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FIG. 1

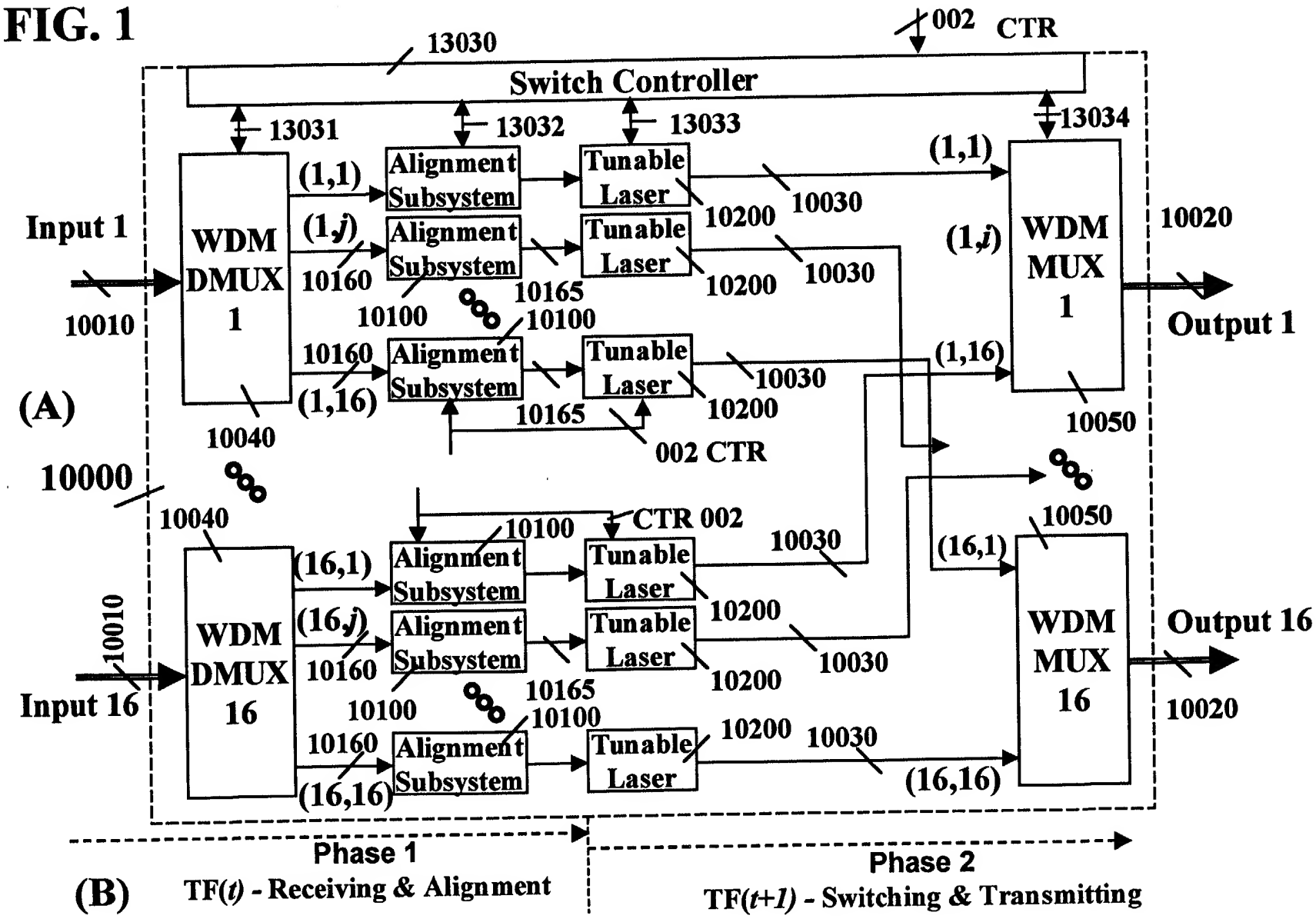

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FIG. 2

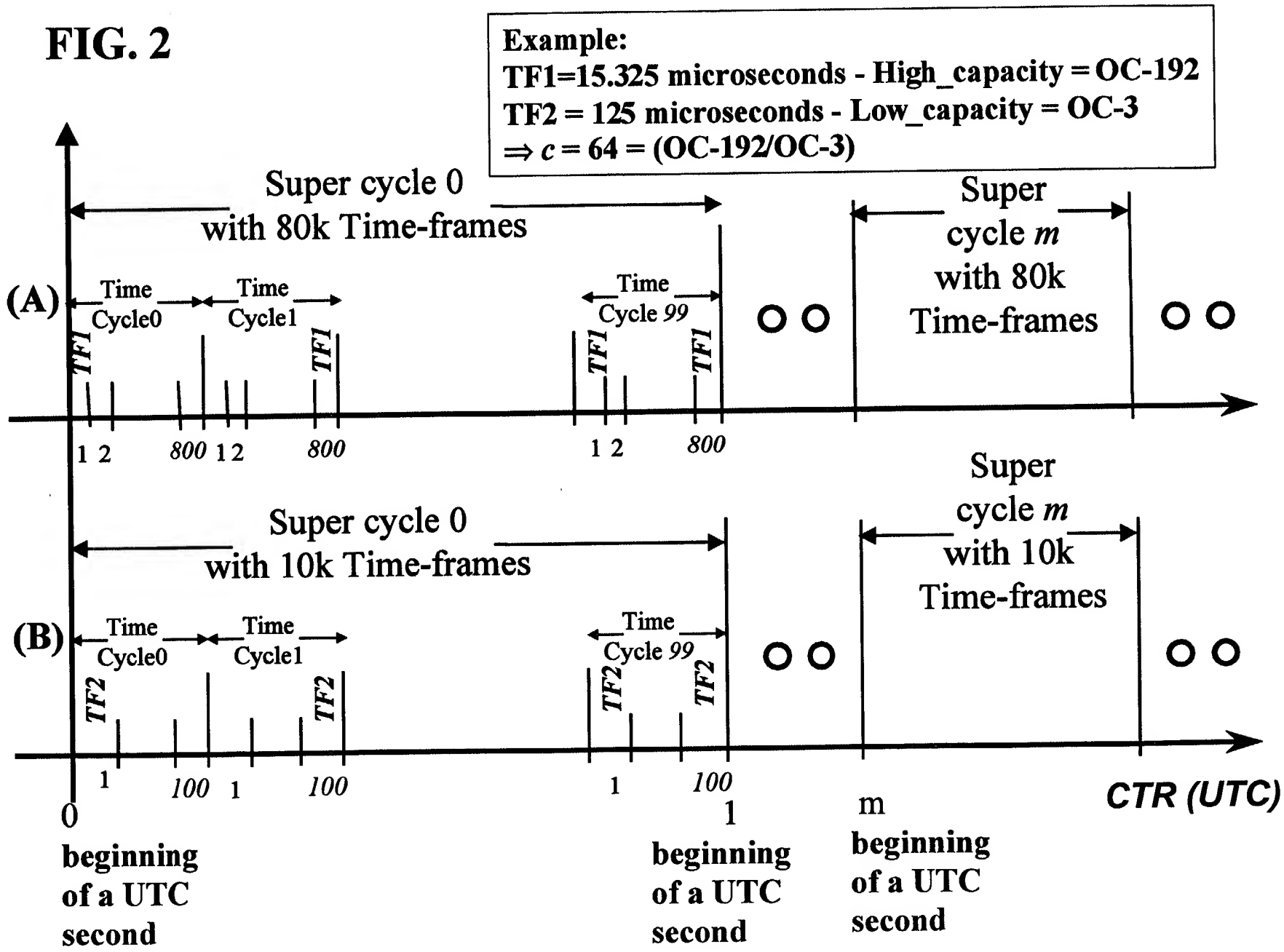

FIG. 3

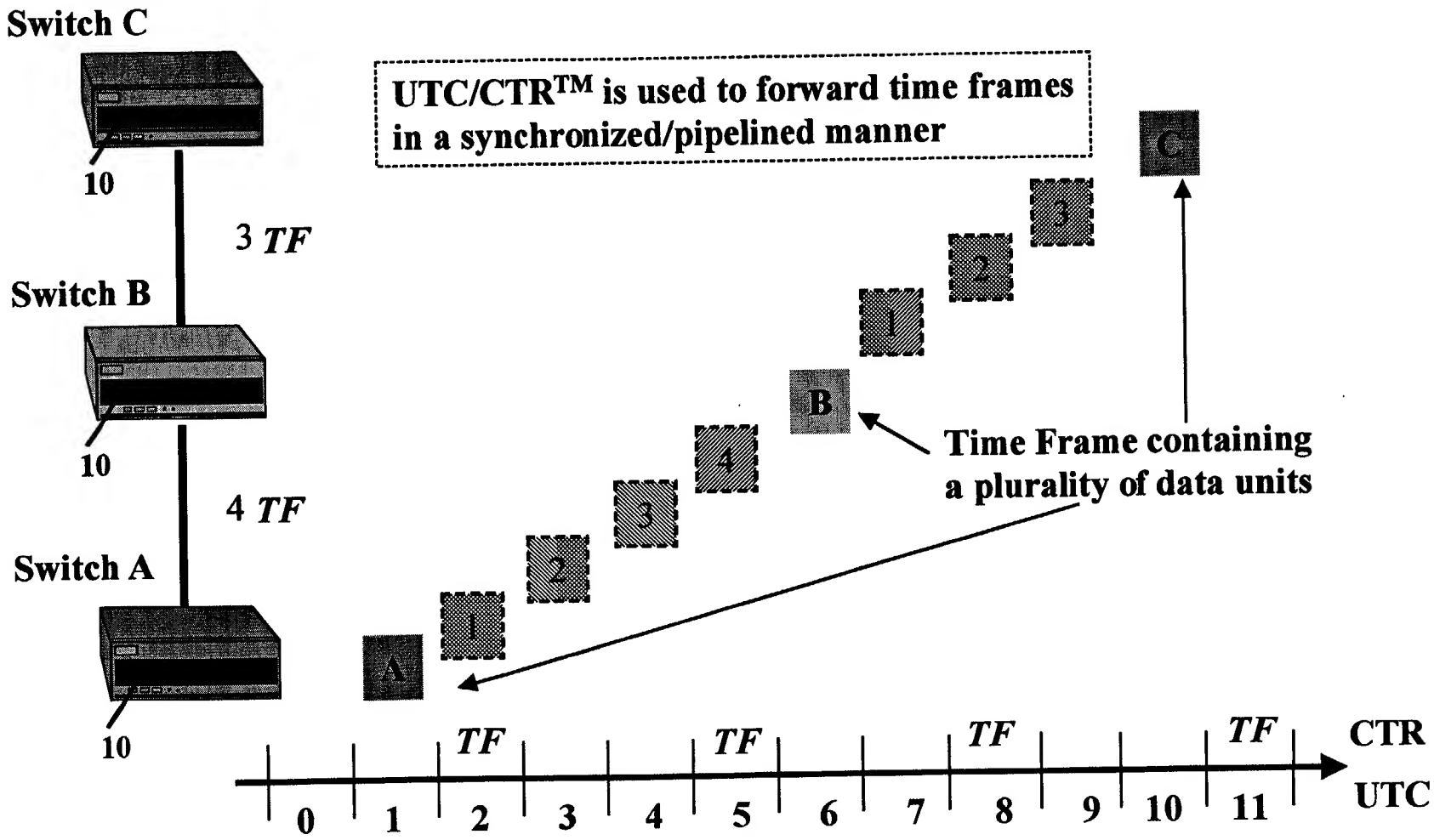
Switch C
10
3 TF
Switch B
10
4 TF
Switch A
10
UTC/CTR™ is used to forward time frames in a synchronized/pipelined manner
A
1
2
3
4
B
1
2
3
C
Time Frame containing a plurality of data units
TF
TF
TF
TF
CTR
UTC
0
1
2
3
4
5
6
7
8
9
10
11

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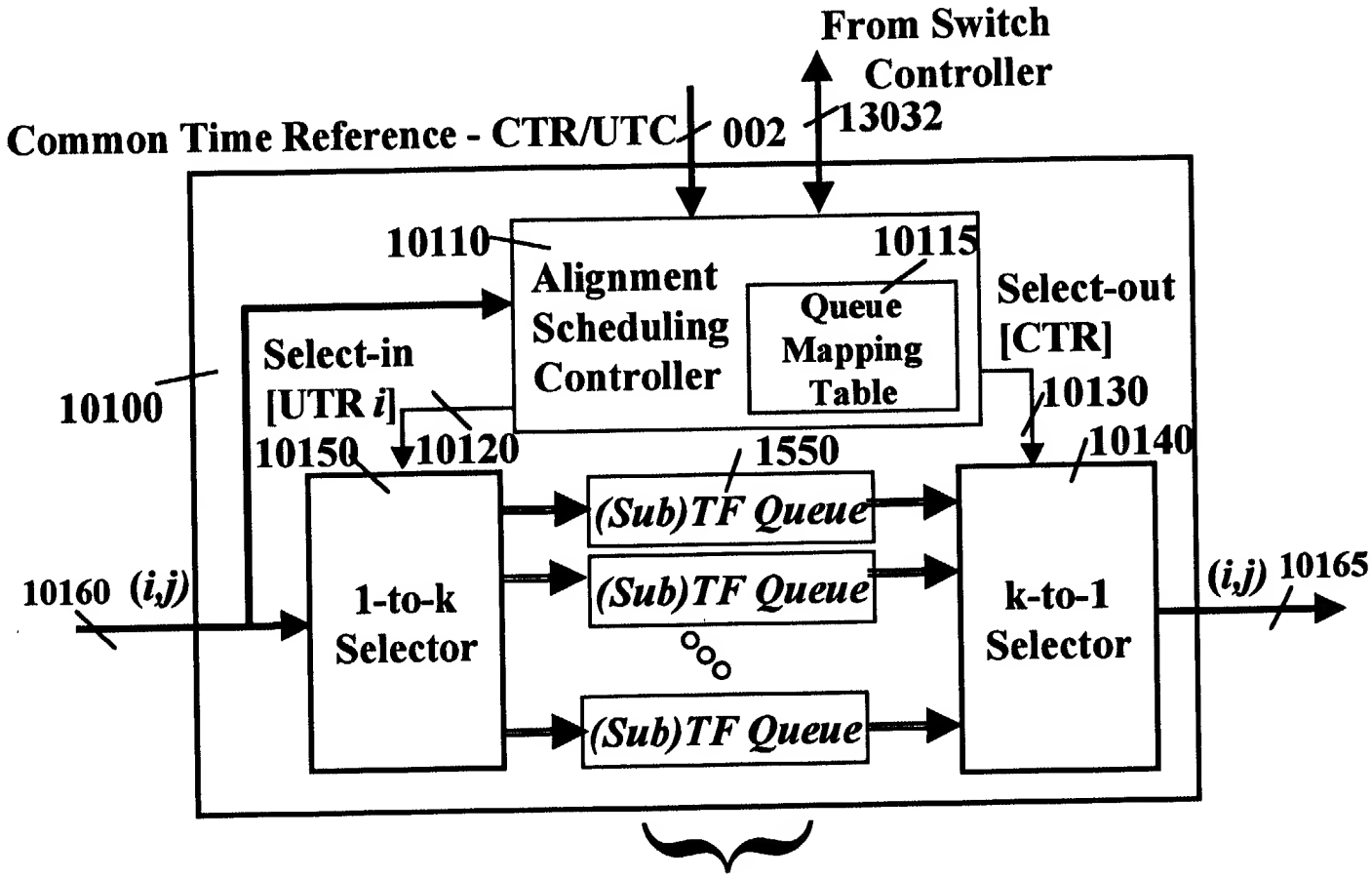
FIG. 4



Alignment Subsystem for *high capacity* Channel *j* at Input Interface *i* with a Plurality of *Sub-Time Frame Queues*

TF*i_j*: Time frame duration on channel *j* at Input Interface *i*.
UTR*i*: UTR on link connected to Input Interface *i*

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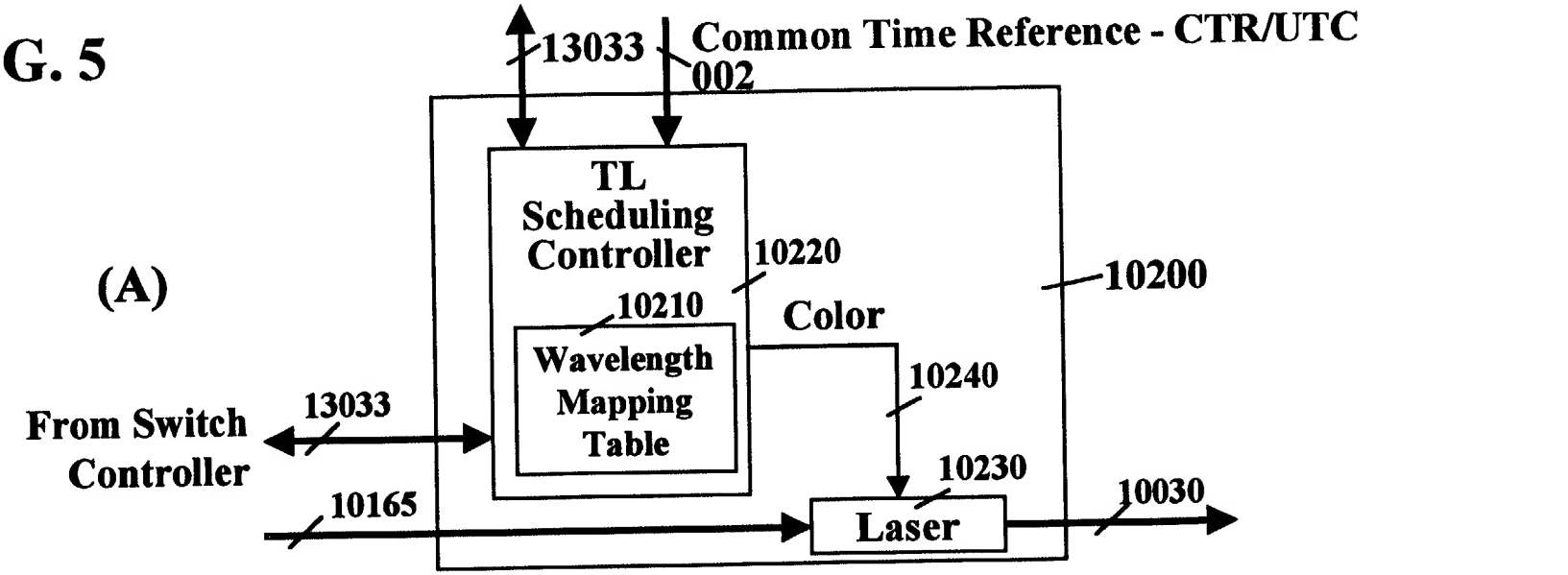
FIG. 5



Implication on a Wavelength Division De-multiplexer of a downstream switching system

FIG. 6

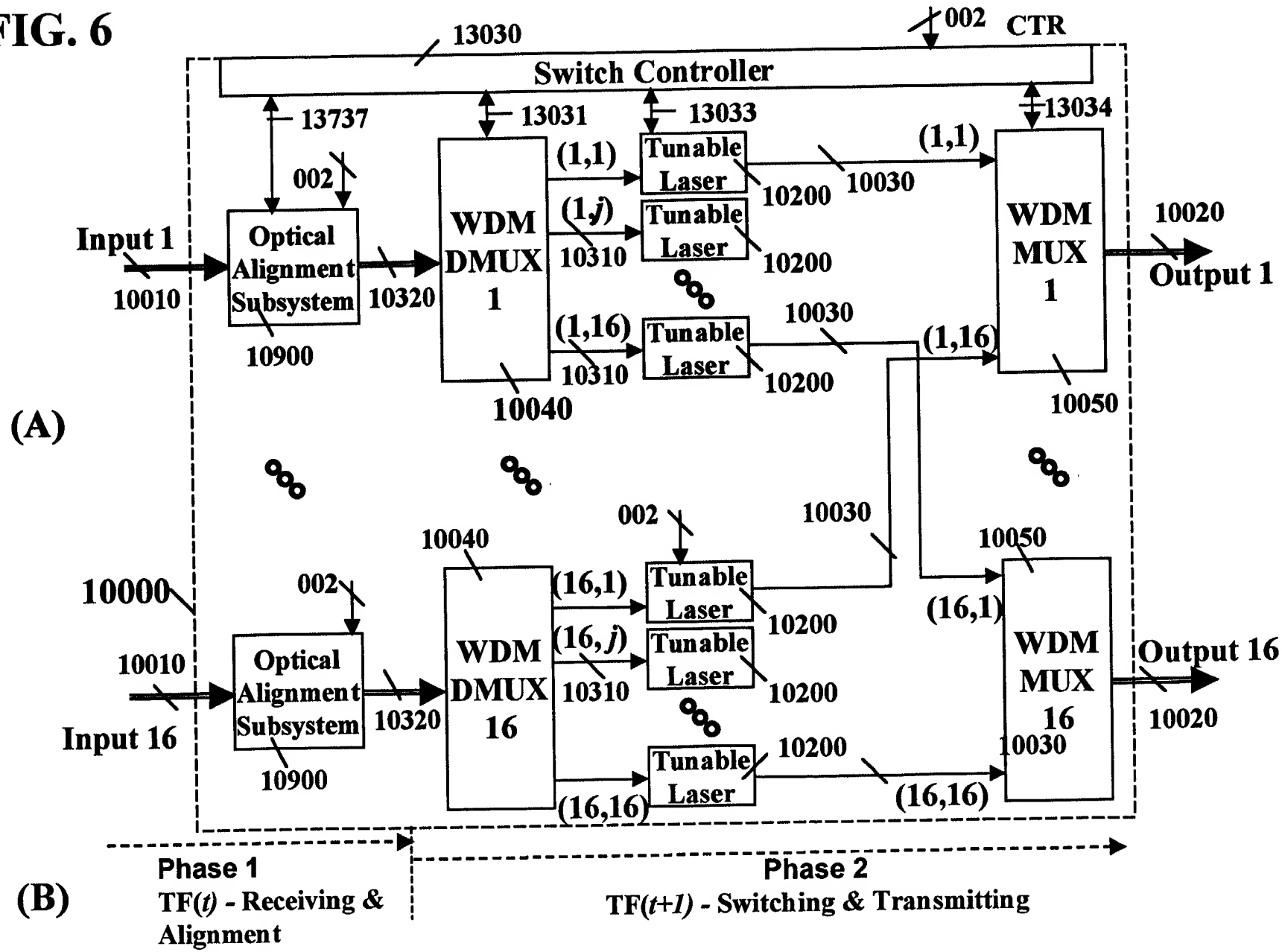

13030
002 CTR
Switch Controller
13737
13031
13033
13034
002
Input 1
10010
Optical Alignment Subsystem
10900
10320
WDM DMUX 1
10040
(1,1)
(1,j)
(1,16)
10310
Tunable Laser
10200
10030
WDM MUX 1
10020
Output 1
(A)
10000
Input 16
10010
Optical Alignment Subsystem
10900
10320
WDM DMUX 16
10040
(16,1)
(16,j)
(16,16)
10310
Tunable Laser
10200
10030
WDM MUX 16
10050
Output 16
10020
(B)
Phase 1
TF(t) - Receiving & Alignment
Phase 2
TF(t+1) - Switching & Transmitting

FIG. 7

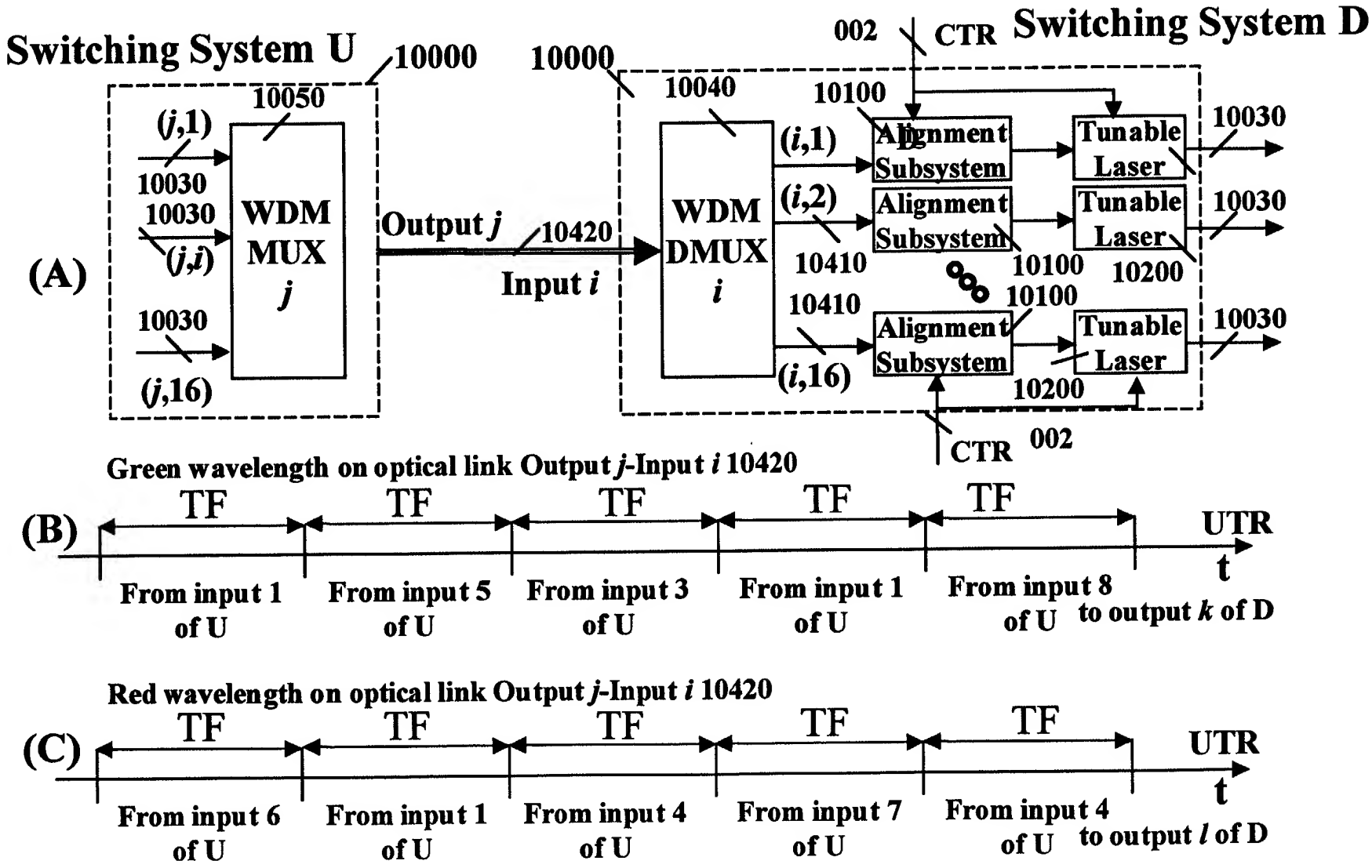


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FIG. 8

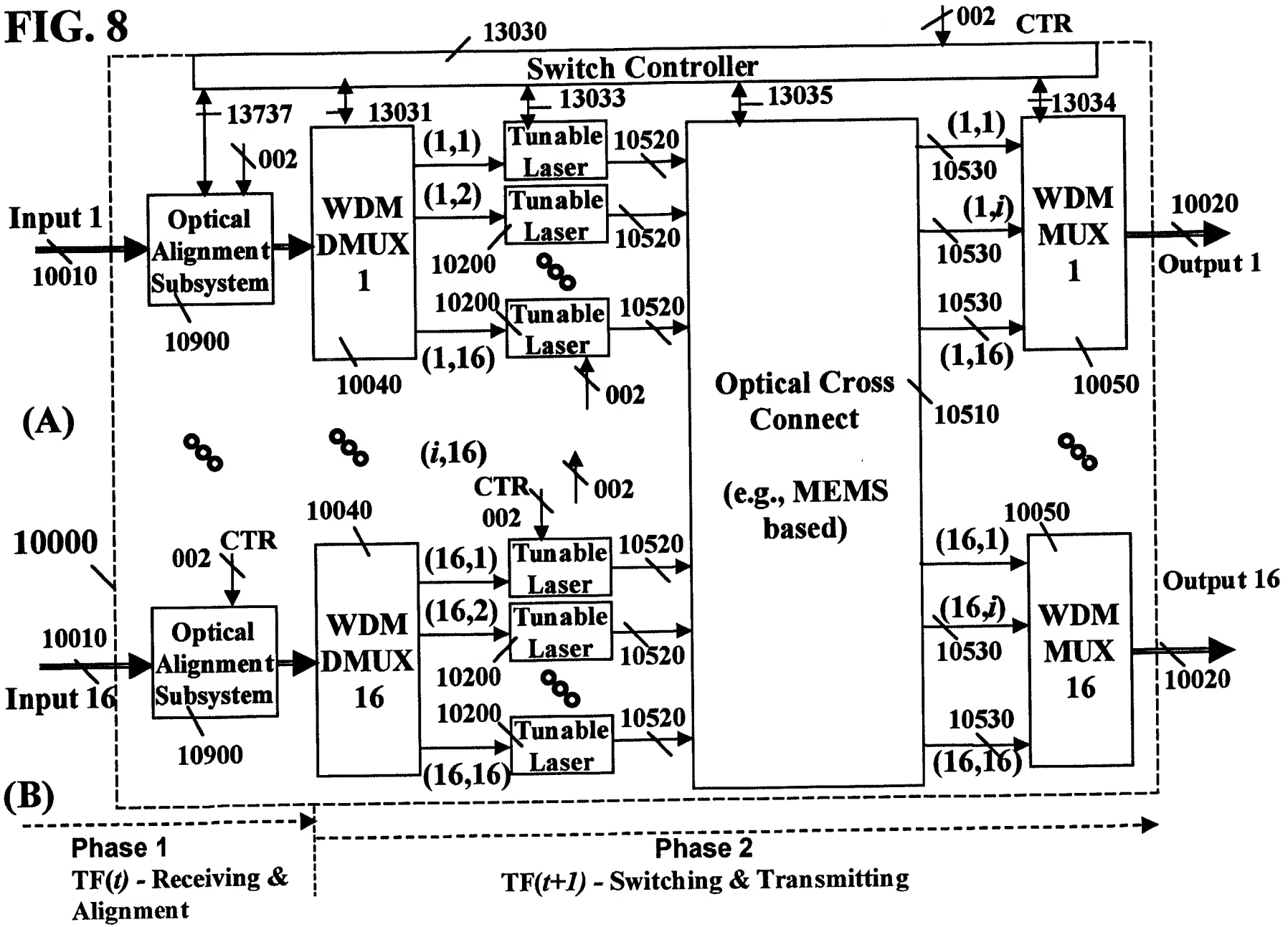
13030
Switch Controller
002 CTR
13737
13031
13033
13035
13034
002
Input 1
10010
Optical Alignment Subsystem
10900
WDM DMUX 1
10040
(1,1)
(1,2)
(1,16)
Tunable Laser
10520
10200
002
Optical Cross Connect
(e.g., MEMS based)
10510
(1,1)
(1,i)
(1,16)
10530
WDM MUX 1
10050
10020
Output 1
(A)
(i,16)
CTR
002
10000
Input 16
10010
Optical Alignment Subsystem
10900
WDM DMUX 16
10040
(16,1)
(16,2)
(16,16)
(16,1)
(16,i)
(16,16)
WDM MUX 16
10050
Output 16
10020
(B)
Phase 1
TF(t) - Receiving & Alignment
Phase 2
TF(t+1) - Switching & Transmitting

FIG. 9

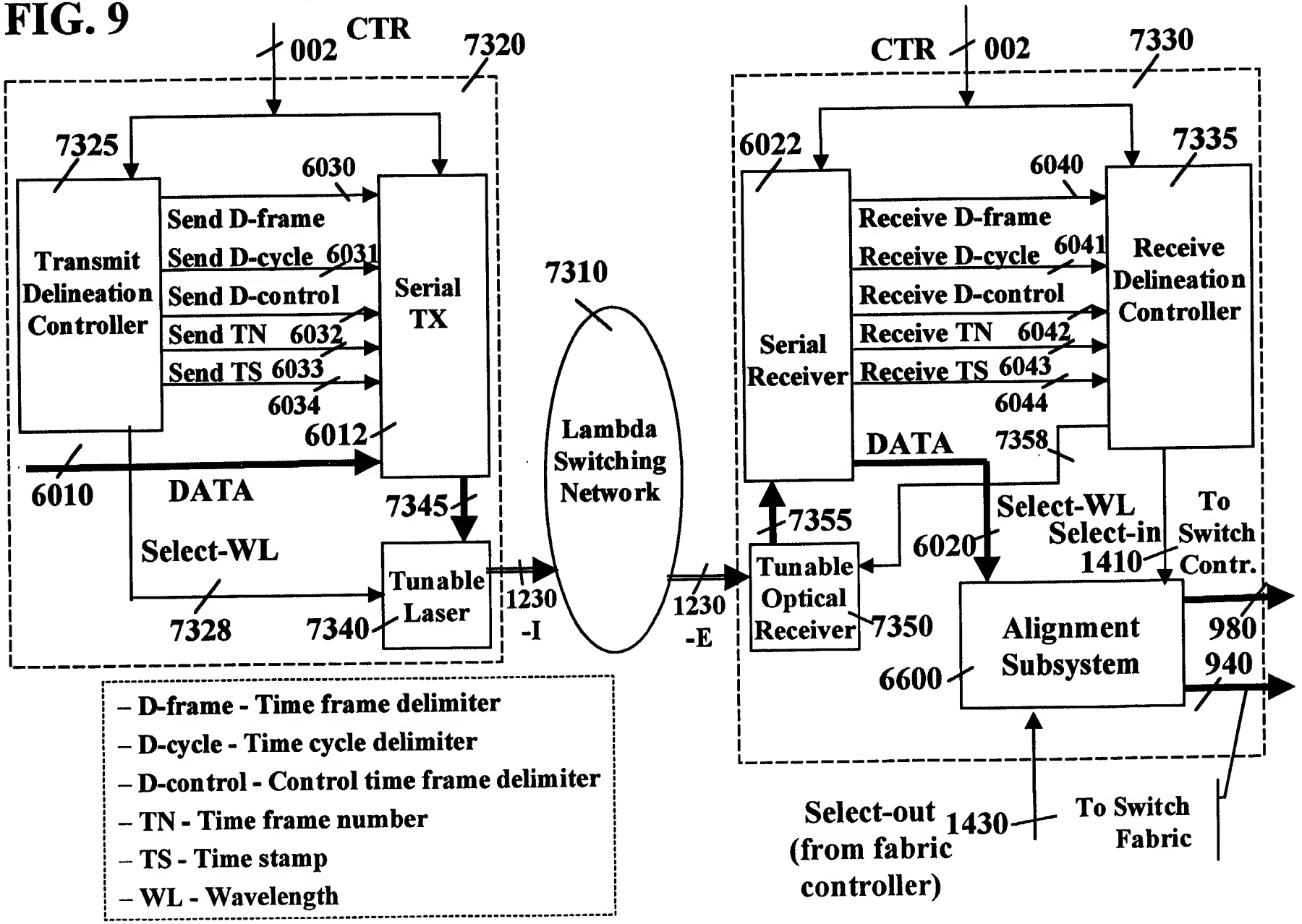
CTR
002
7320
7325
6030
Transmit Delineation Controller
Send D-frame
Send D-cycle 6031
Send D-control
Send TN 6032
Send TS 6033
6034
Serial TX
6012
6010
DATA
7345
Select-WL
7328
Tunable Laser
7340
1230 -I
7310
Lambda Switching Network
1230 -E
CTR
002
7330
6022
Serial Receiver
6040
Receive D-frame
Receive D-cycle 6041
Receive D-control
Receive TN 6042
Receive TS 6043
6044
Receive Delineation Controller
7335
DATA
7358
7355
Tunable Optical Receiver
7350
6020
Select-WL
Select-in 1410
To Switch Contr.
Alignment Subsystem
6600
980
940
Select-out (from fabric controller)
1430
To Switch Fabric
– D-frame - Time frame delimiter
– D-cycle - Time cycle delimiter
– D-control - Control time frame delimiter
– TN - Time frame number
– TS - Time stamp
– WL - Wavelength

FIG. 10

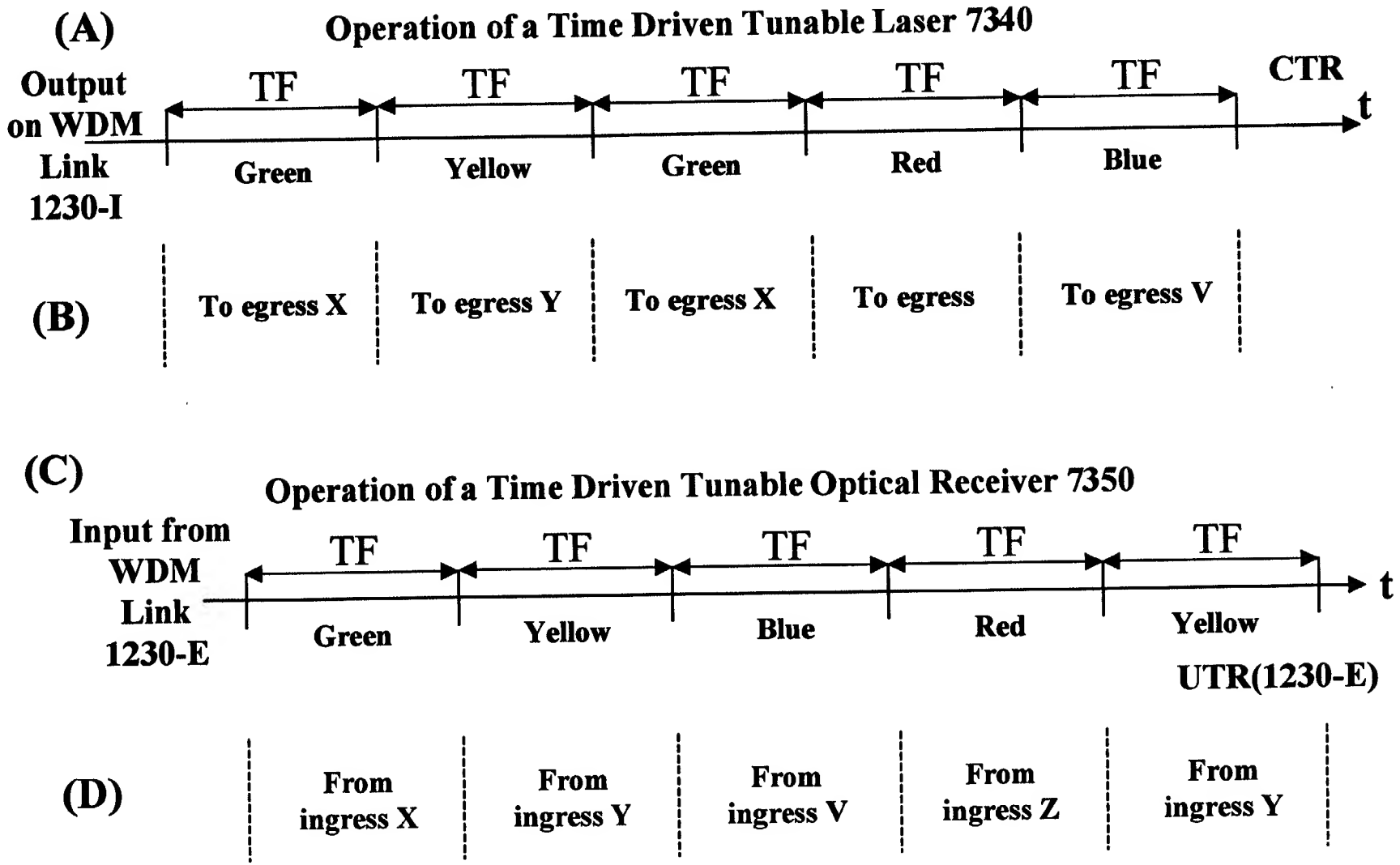
(A)
Operation of a Time Driven Tunable Laser 7340
Output on WDM Link 1230-I
TF
TF
TF
TF
TF
CTR
t
Green
Yellow
Green
Red
Blue
(B)
To egress X
To egress Y
To egress X
To egress
To egress V
(C)
Operation of a Time Driven Tunable Optical Receiver 7350
Input from WDM Link 1230-E
TF
TF
TF
TF
TF
t
Green
Yellow
Blue
Red
Yellow
UTR(1230-E)
(D)
From ingress X
From ingress Y
From ingress V
From ingress Z
From ingress Y

FIG. 11

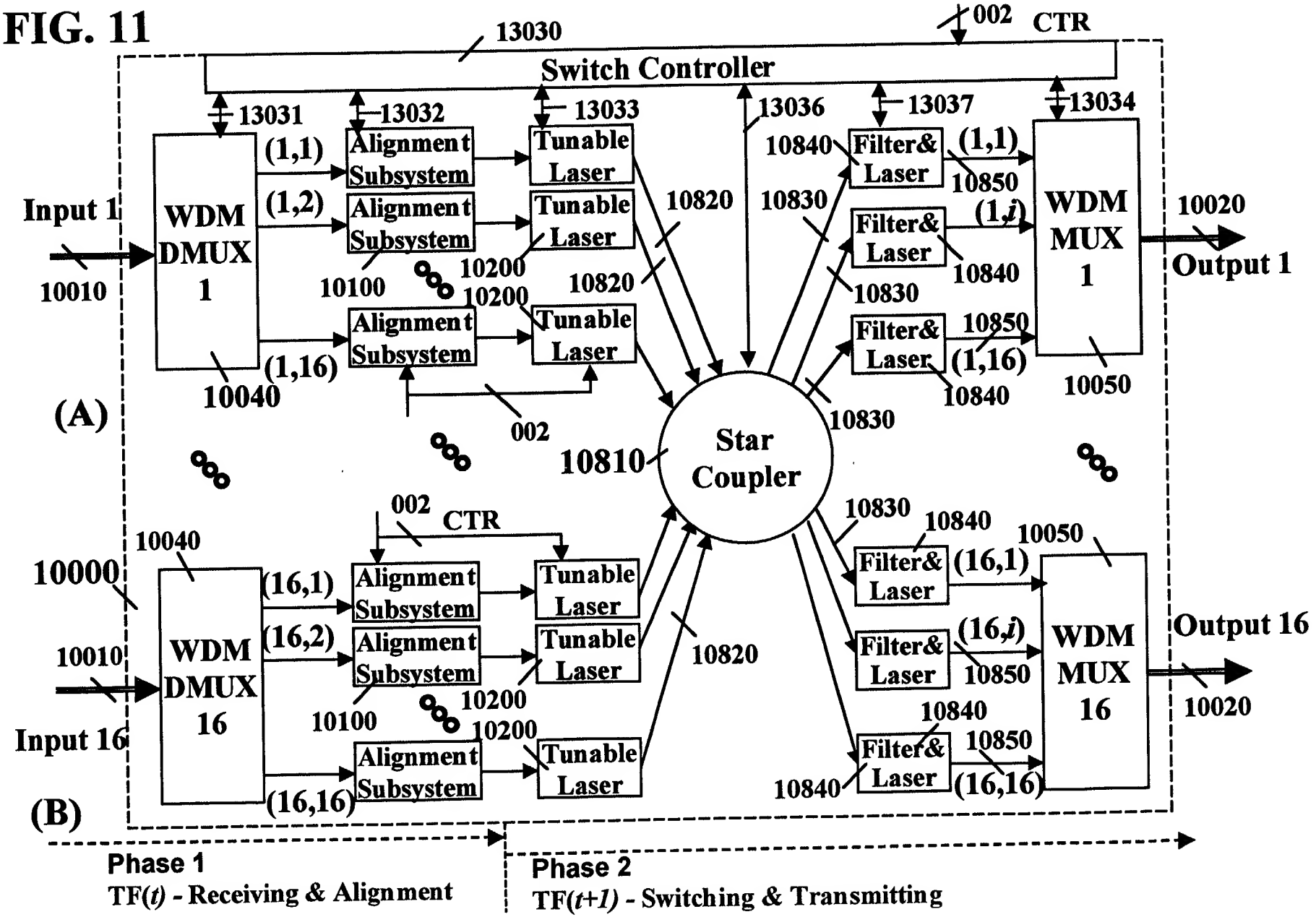
13030
Switch Controller
002 CTR
13031
13032
13033
13036
13037
13034
Input 1
10010
WDM DMUX 1
(1,1)
(1,2)
(1,16)
10040
Alignment Subsystem
Tunable Laser
10100
10200
10820
10840
Filter& Laser
10850
10830
(1,1)
(1,i)
(1,16)
WDM MUX 1
10020
Output 1
10050
(A)
002
10810
Star Coupler
Input 16
10000
(16,1)
(16,2)
(16,16)
WDM DMUX 16
(16,1)
(16,i)
(16,16)
WDM MUX 16
Output 16
(B)
Phase 1
TF(t) - Receiving & Alignment
Phase 2
TF(t+1) - Switching & Transmitting

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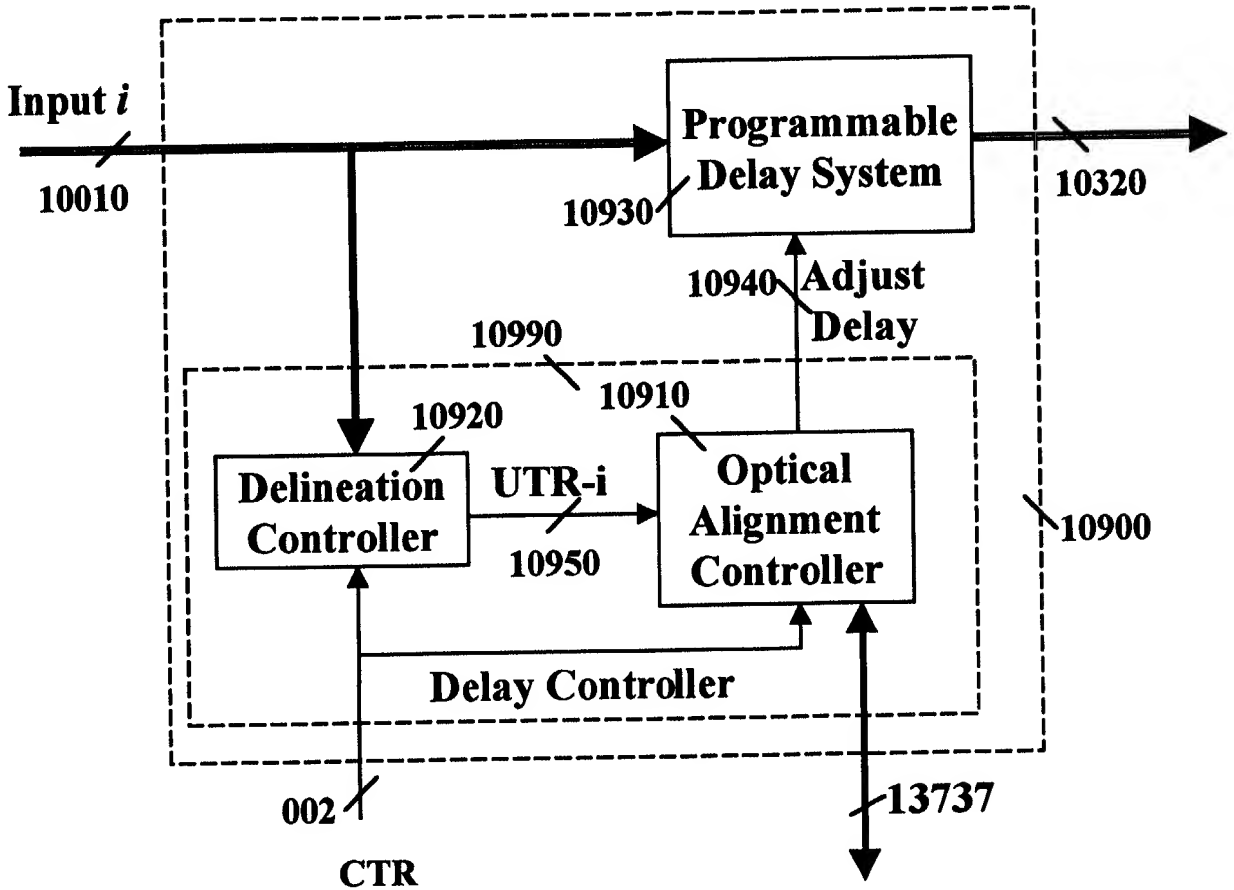
FIG. 12



UTR-i: Unique Time Reference of input link *i*
CTR: Common Time Reference

FIG. 13

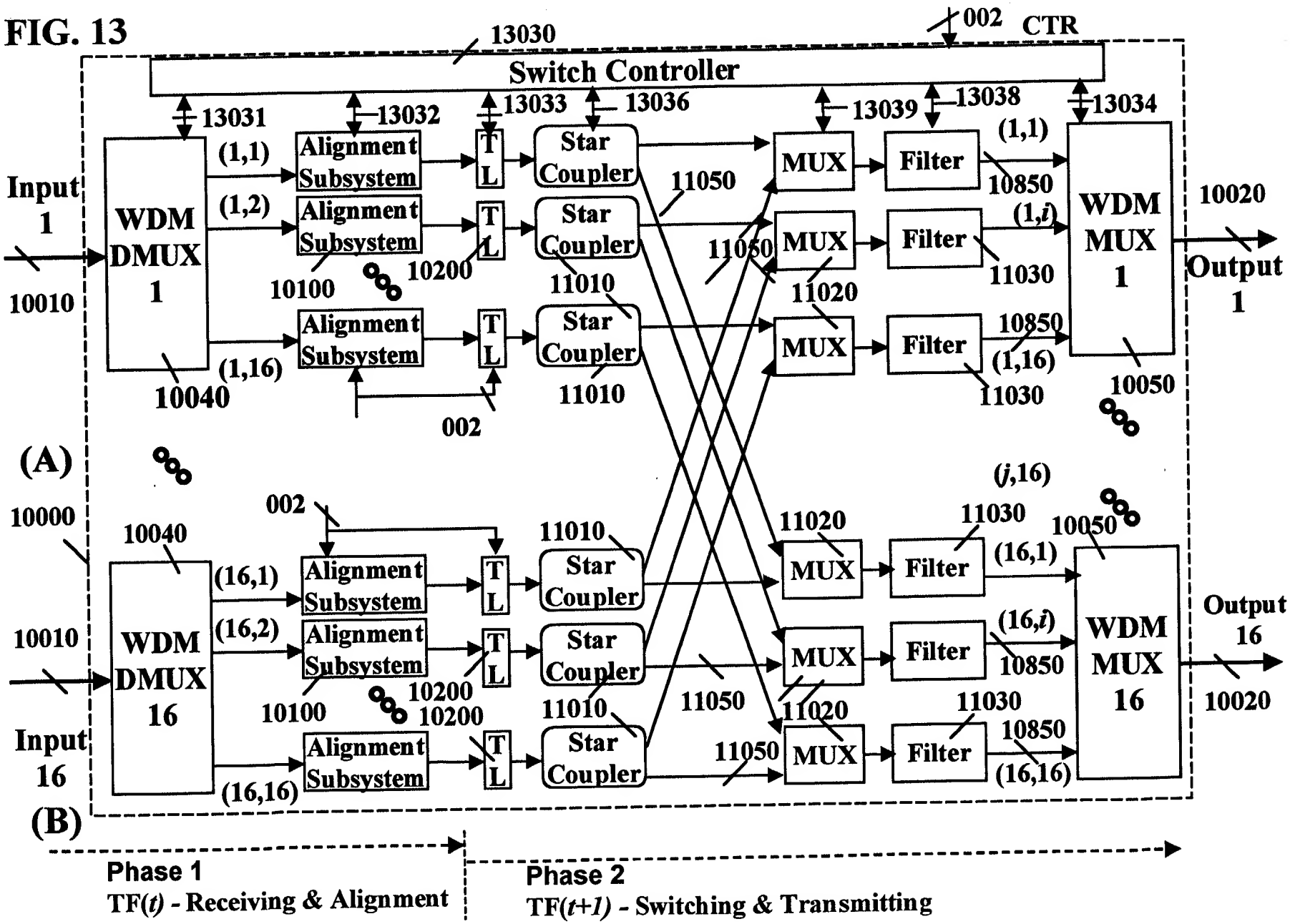

002 CTR
13030
Switch Controller
13031
13032
13033
13036
13039
13038
13034
Input 1
10010
WDM DMUX 1
10040
(1,1)
(1,2)
(1,16)
Alignment Subsystem
TL
10100
10200
002
Star Coupler
11010
11050
MUX
11020
Filter
10850
(1,1)
(1,i)
(1,16)
11030
WDM MUX 1
10050
10020
Output 1
(A)
(j,16)
10000
Input 16
WDM DMUX 16
(16,1)
(16,2)
(16,16)
(16,1)
(16,i)
(16,16)
Output 16
(B)
Phase 1
TF(t) - Receiving & Alignment
Phase 2
TF(t+1) - Switching & Transmitting

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FIG. 14

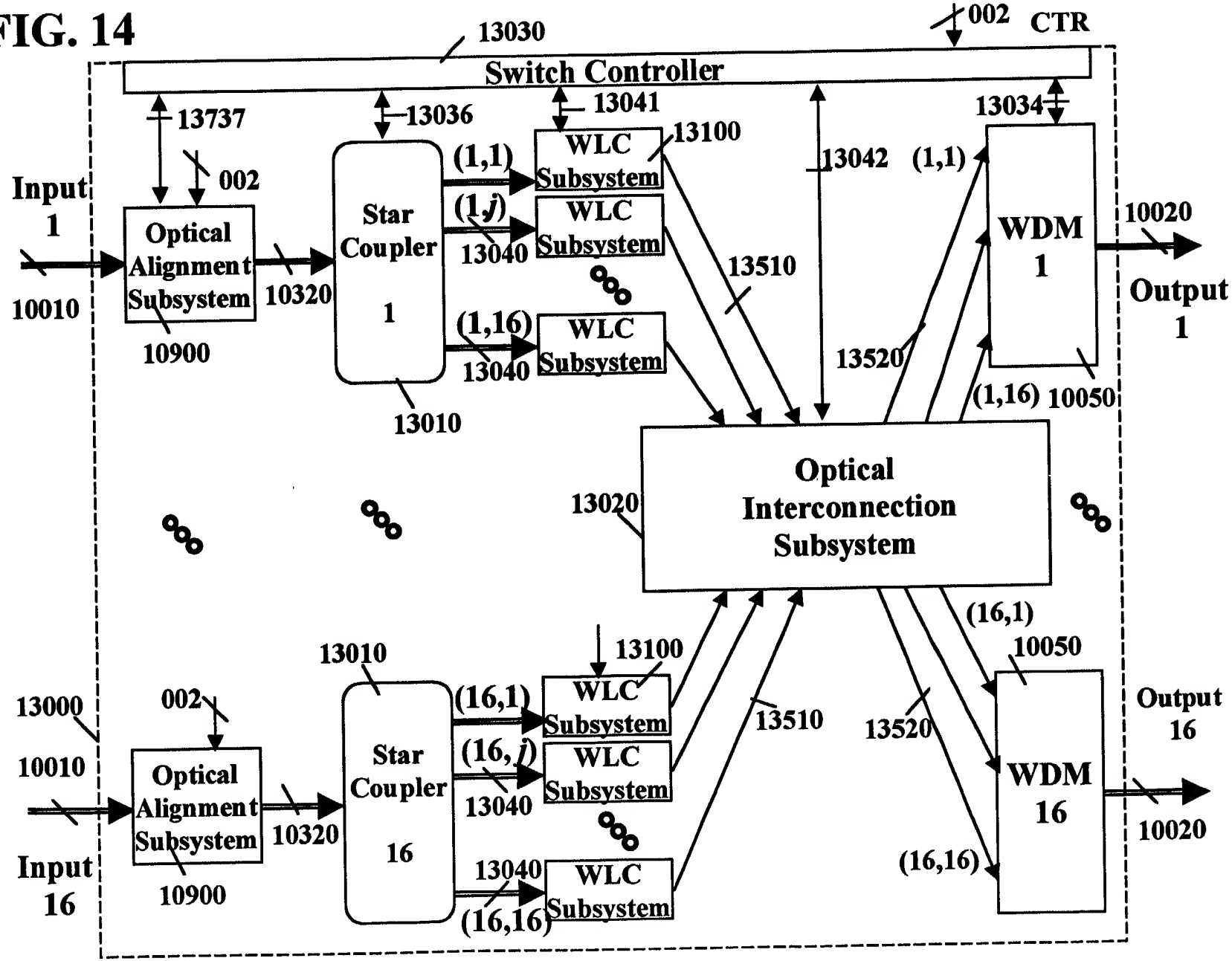
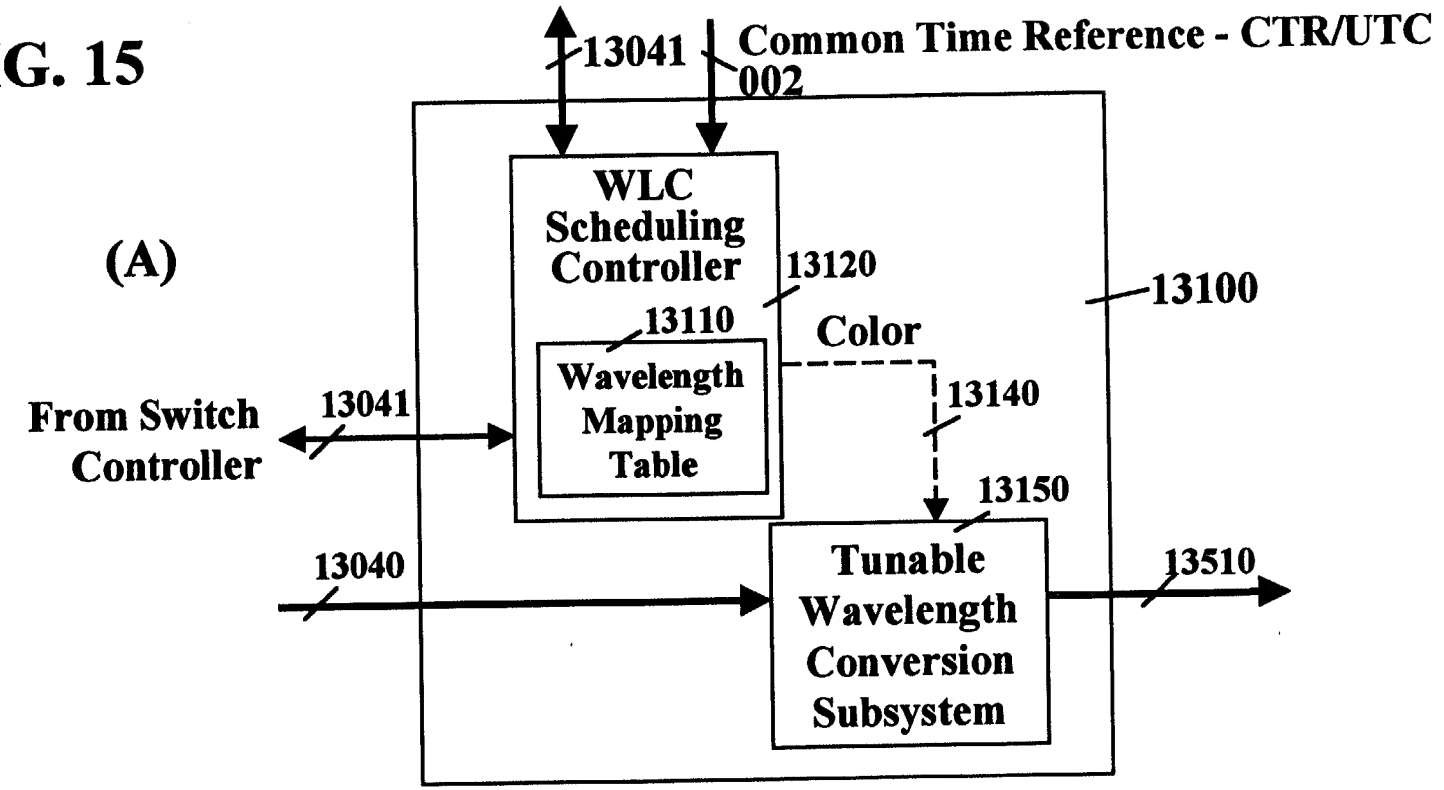
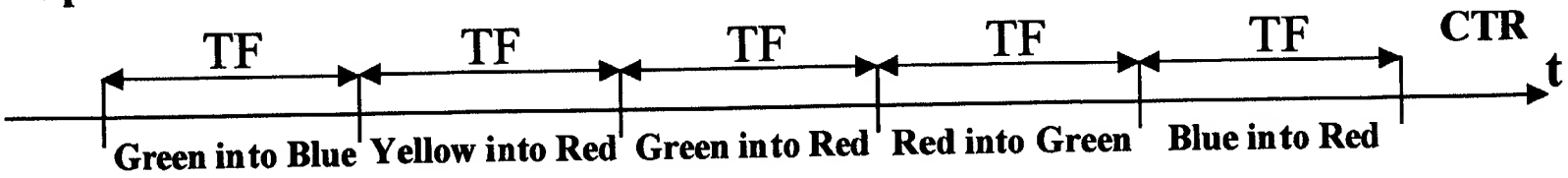


FIG. 15



(B)

Operation of a Time Driven Tunable Wavelength Conversion Subsystem 13150



Wavelengths received 13040 and emitted 13510 by
Tunable Wavelength Conversion Subsystem 13150

FIG. 16

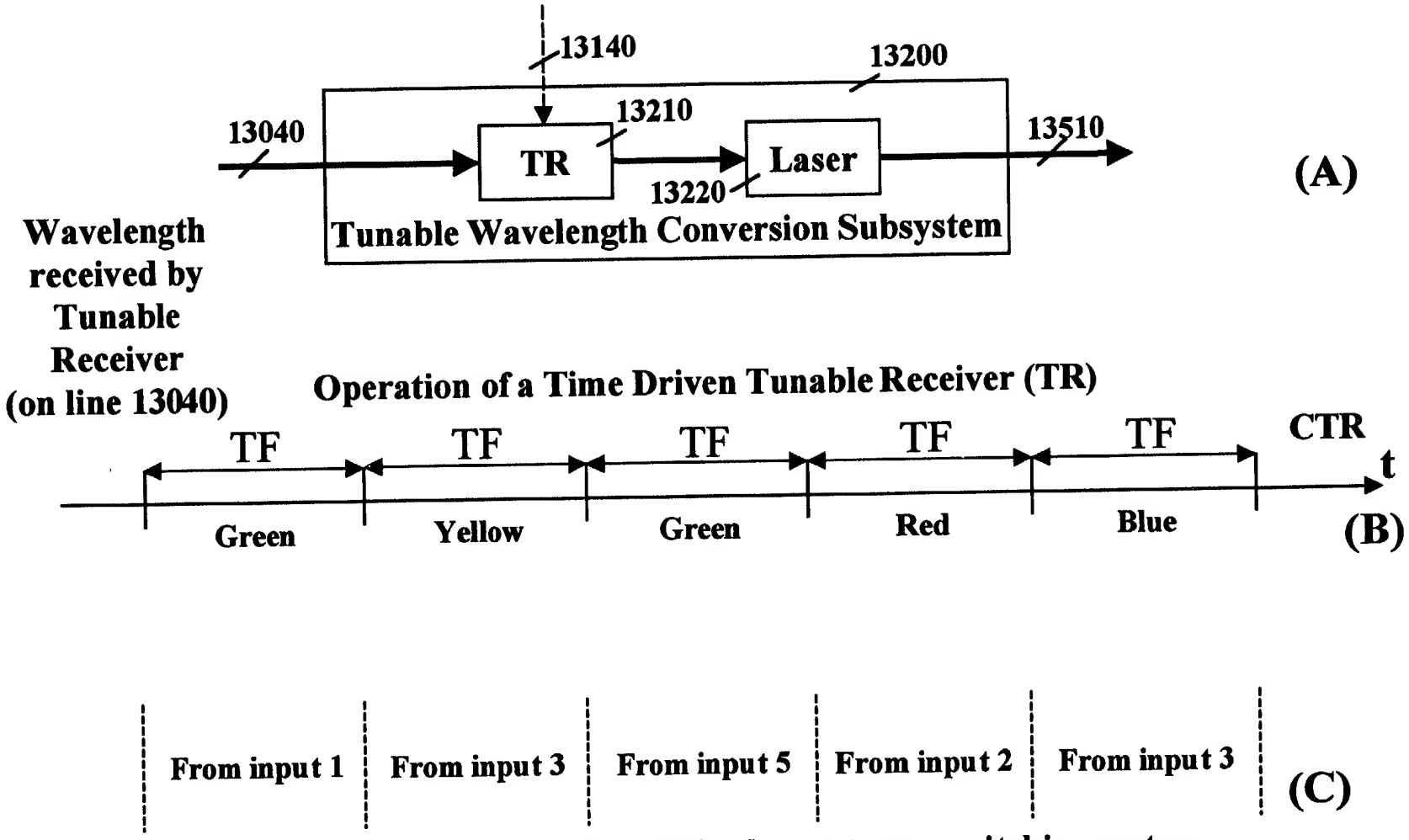
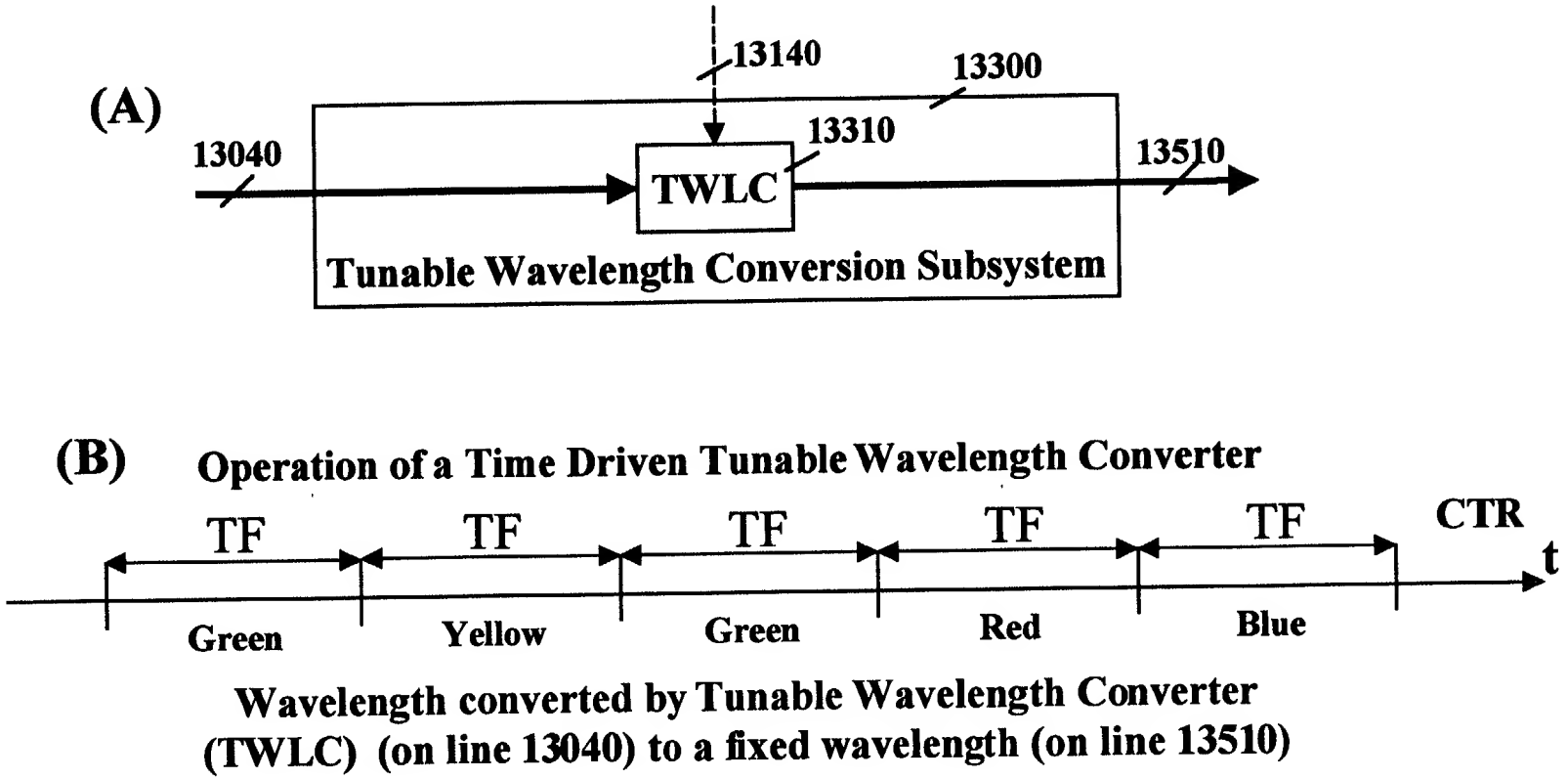

13140
13200
13040
13210
TR
Laser
13510
13220
Tunable Wavelength Conversion Subsystem
(A)
Wavelength received by Tunable Receiver (on line 13040)
Operation of a Time Driven Tunable Receiver (TR)
TF
TF
TF
TF
TF
CTR
t
Green
Yellow
Green
Red
Blue
(B)
From input 1
From input 3
From input 5
From input 2
From input 3
(C)
Origin of data units within the upstream switching system

FIG. 17



Wavelength converted by Tunable Wavelength Converter (TWLC) (on line 13040) to a fixed wavelength (on line 13510)

FIG. 18

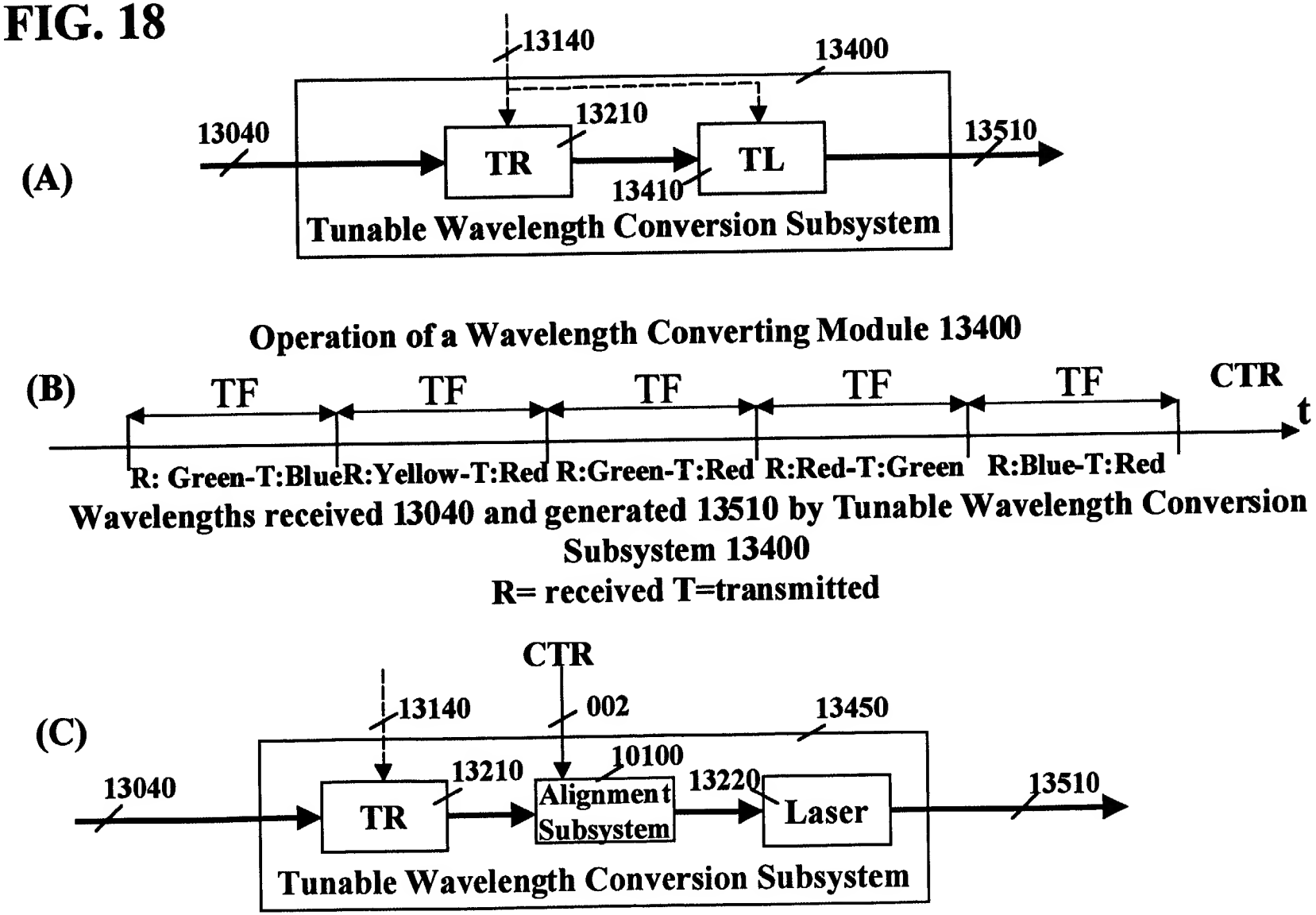

(A)
13140
13400
13040
13210
TR
TL
13510
13410
Tunable Wavelength Conversion Subsystem
Operation of a Wavelength Converting Module 13400
(B)
TF
TF
TF
TF
TF
CTR
t
R: Green-T:Blue
R:Yellow-T:Red
R:Green-T:Red
R:Red-T:Green
R:Blue-T:Red
Wavelengths received 13040 and generated 13510 by Tunable Wavelength Conversion Subsystem 13400
R= received T=transmitted
(C)
CTR
13140
002
13450
10100
13040
13210
TR
Alignment Subsystem
13220
Laser
13510
Tunable Wavelength Conversion Subsystem

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FIG. 19

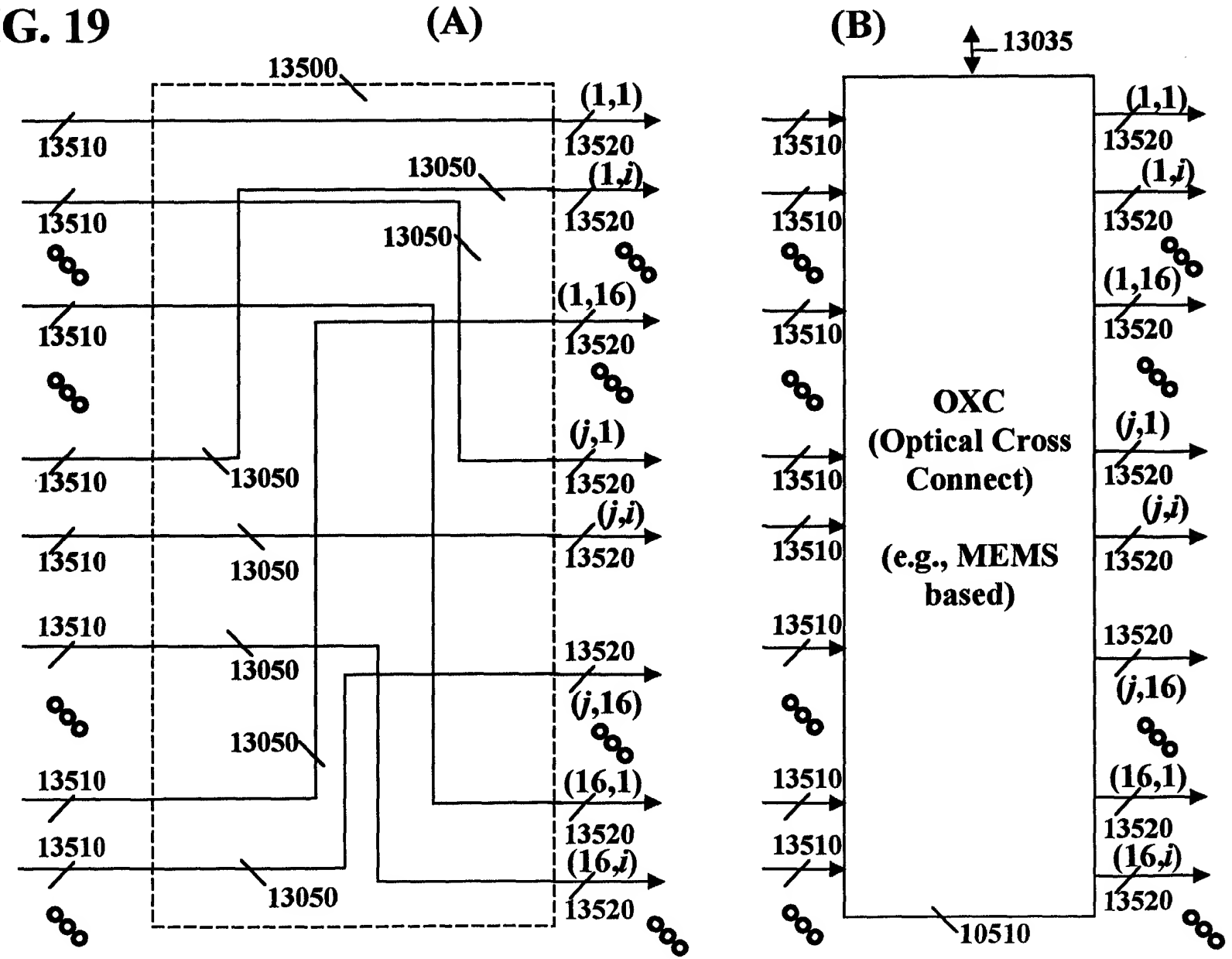


FIG. 20

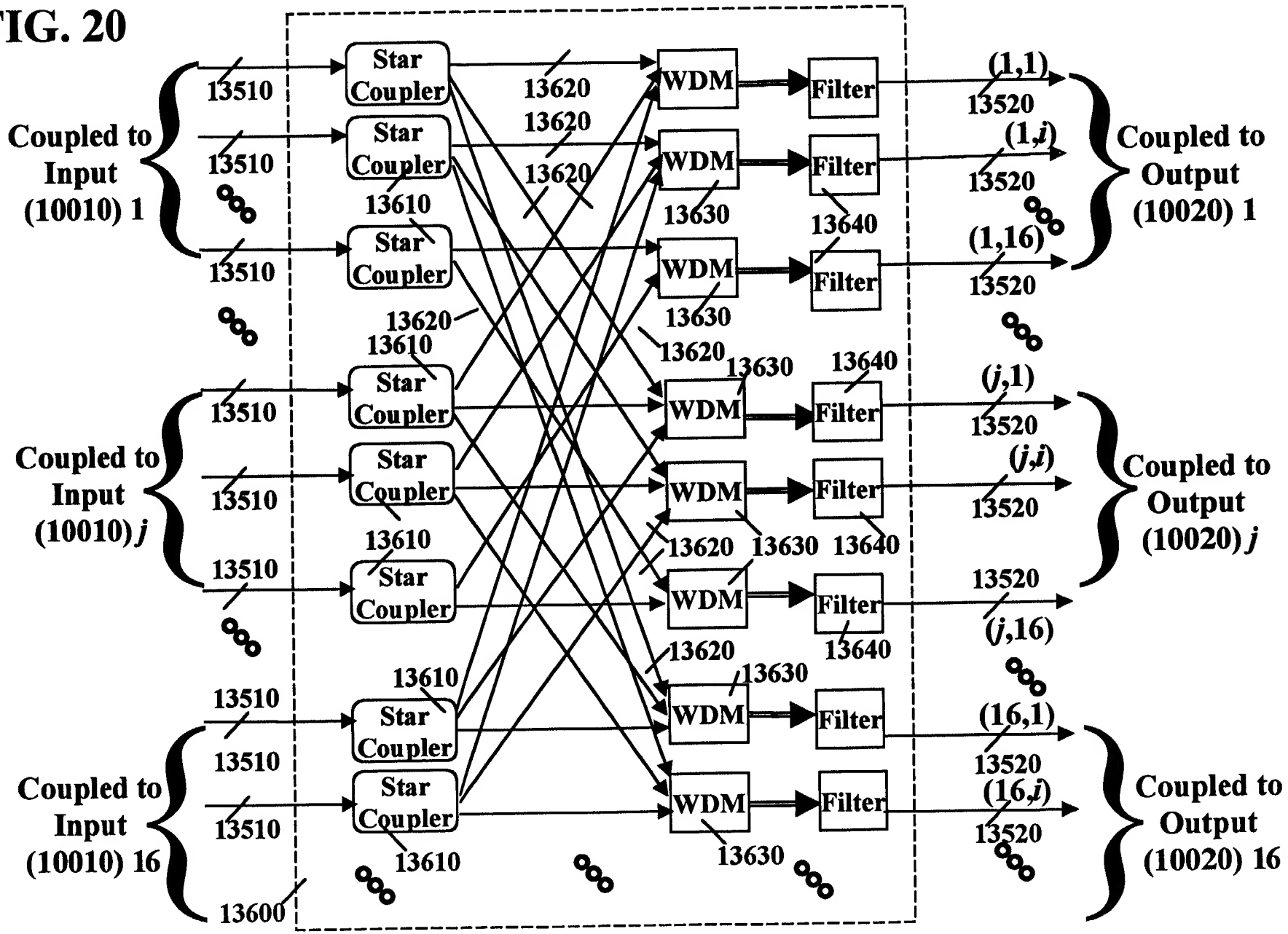

Coupled to Input (10010) 1
Coupled to Input (10010) j
Coupled to Input (10010) 16
13510
13600
Star Coupler
13610
13620
WDM
13630
Filter
13640
(1,1)
(1,i)
(1,16)
(j,1)
(j,i)
(j,16)
(16,1)
(16,i)
13520
Coupled to Output (10020) 1
Coupled to Output (10020) j
Coupled to Output (10020) 16

FIG. 21

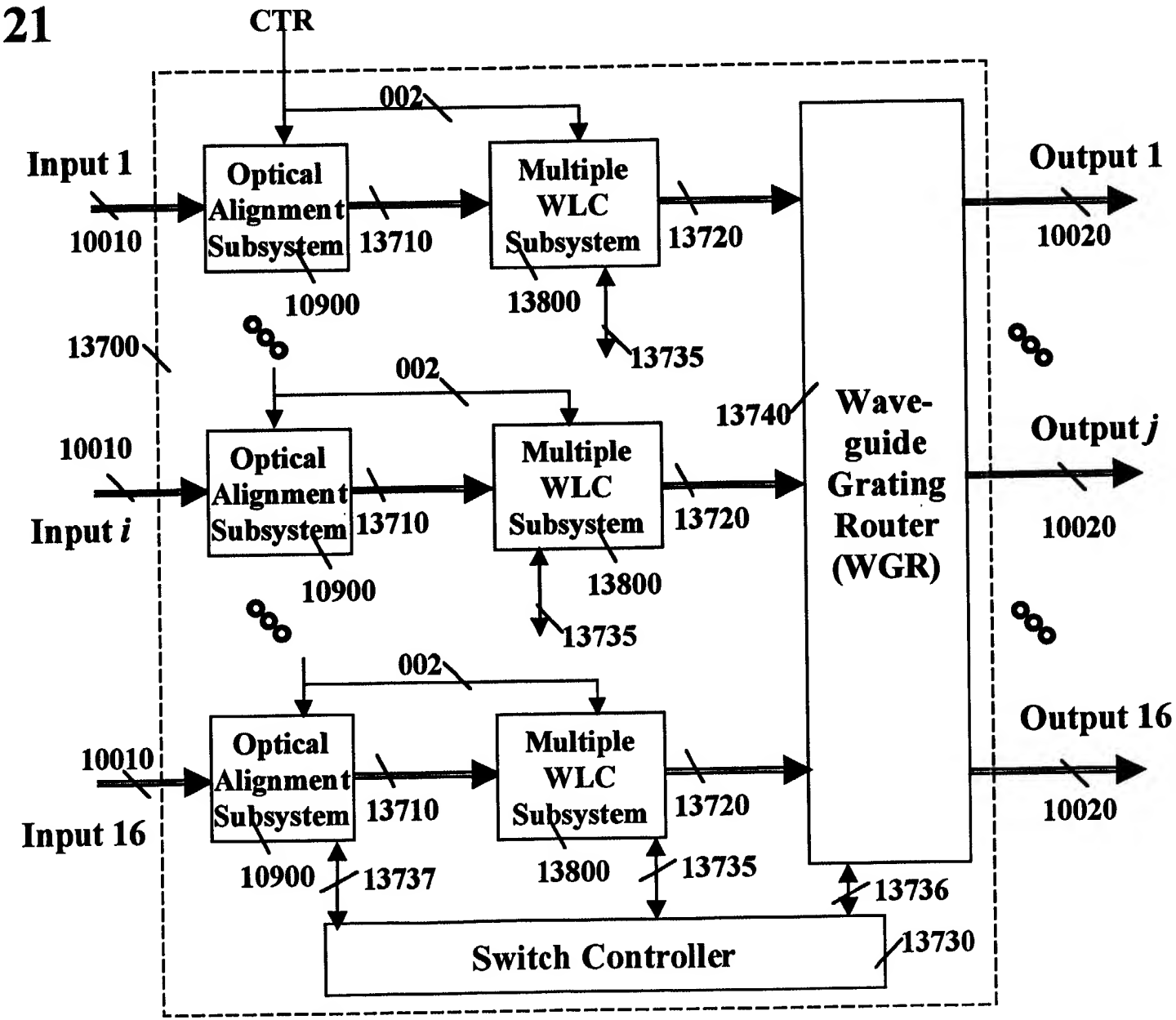
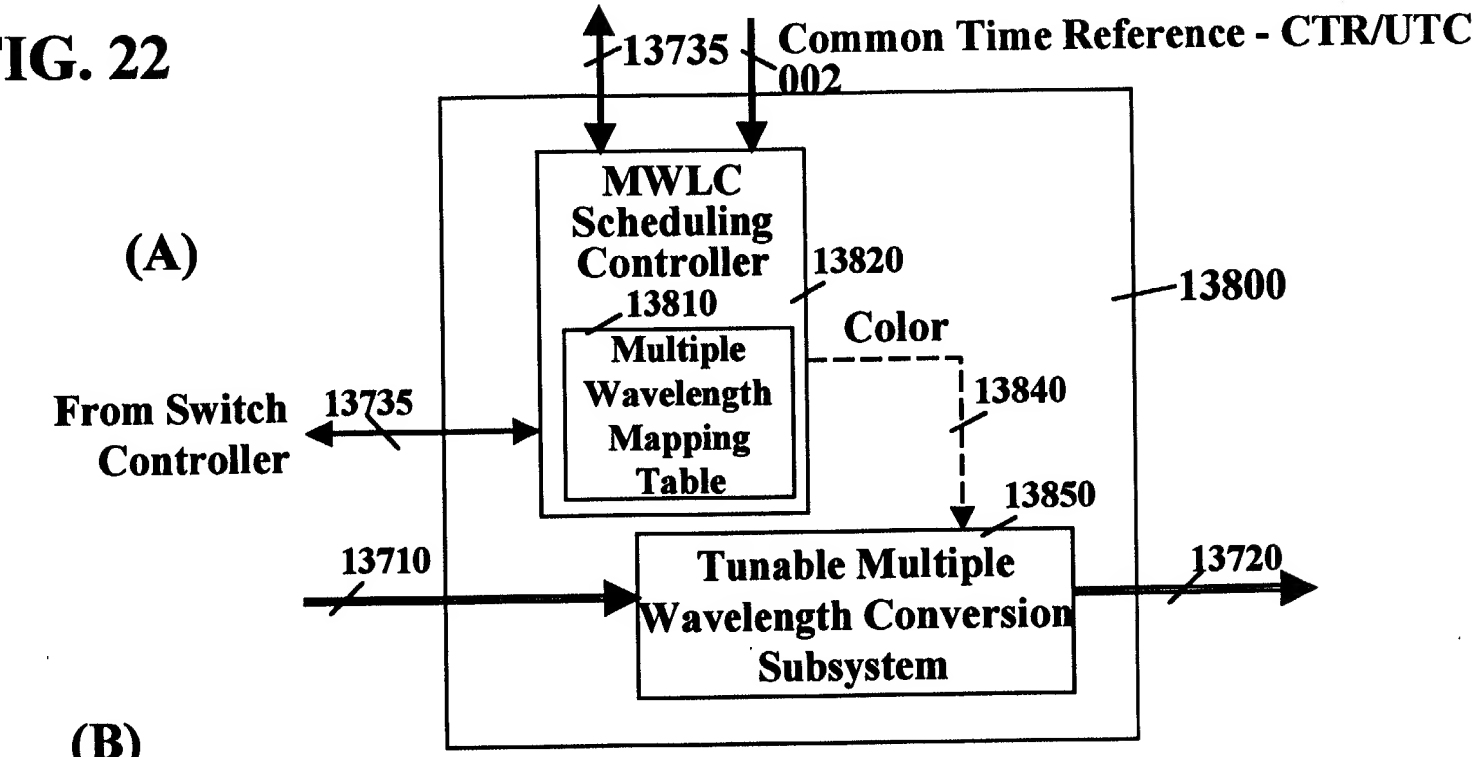
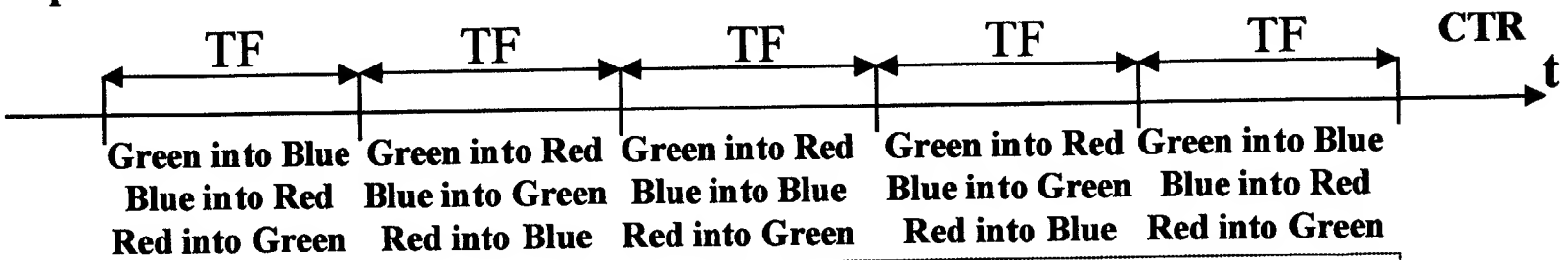

CTR
002
Input 1
10010
Optical Alignment Subsystem
13710
Multiple WLC Subsystem
13720
Output 1
10020
10900
13800
13735
13700
002
13740
Wave-guide Grating Router (WGR)
10010
Optical Alignment Subsystem
13710
Multiple WLC Subsystem
13720
Output j
10020
Input i
10900
13800
13735
002
Output 16
10010
Optical Alignment Subsystem
13710
Multiple WLC Subsystem
13720
10020
Input 16
10900
13737
13800
13735
13736
Switch Controller
13730

FIG. 22



Operation of a Time Driven Tunable Multiple Wavelength Conversion Subsystem 13850



Wavelengths received 13710 and emitted 13720 by a Tunable Multiple Wavelength Conversion Subsystem 13850

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FIG. 23

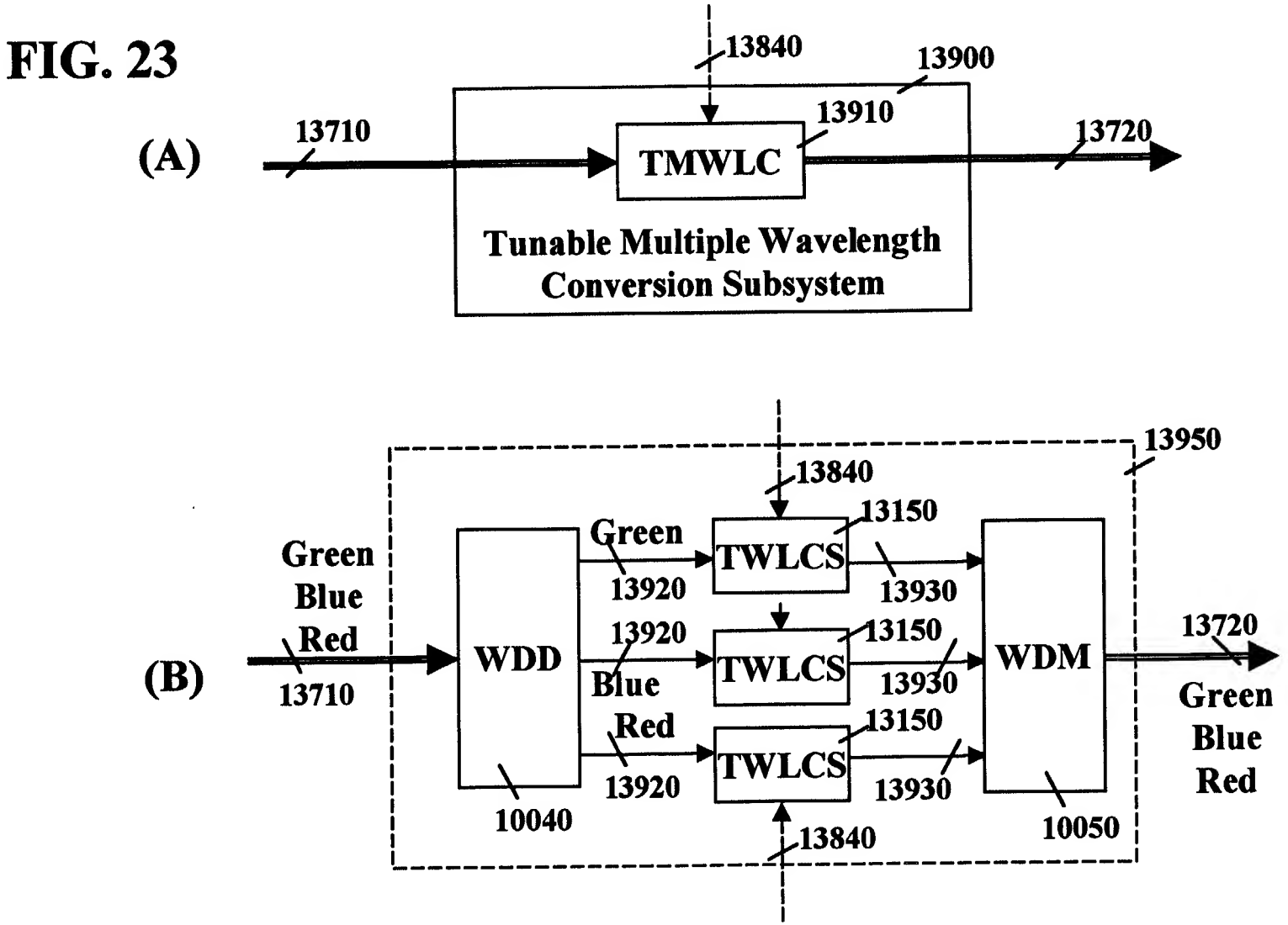

FIG. 24

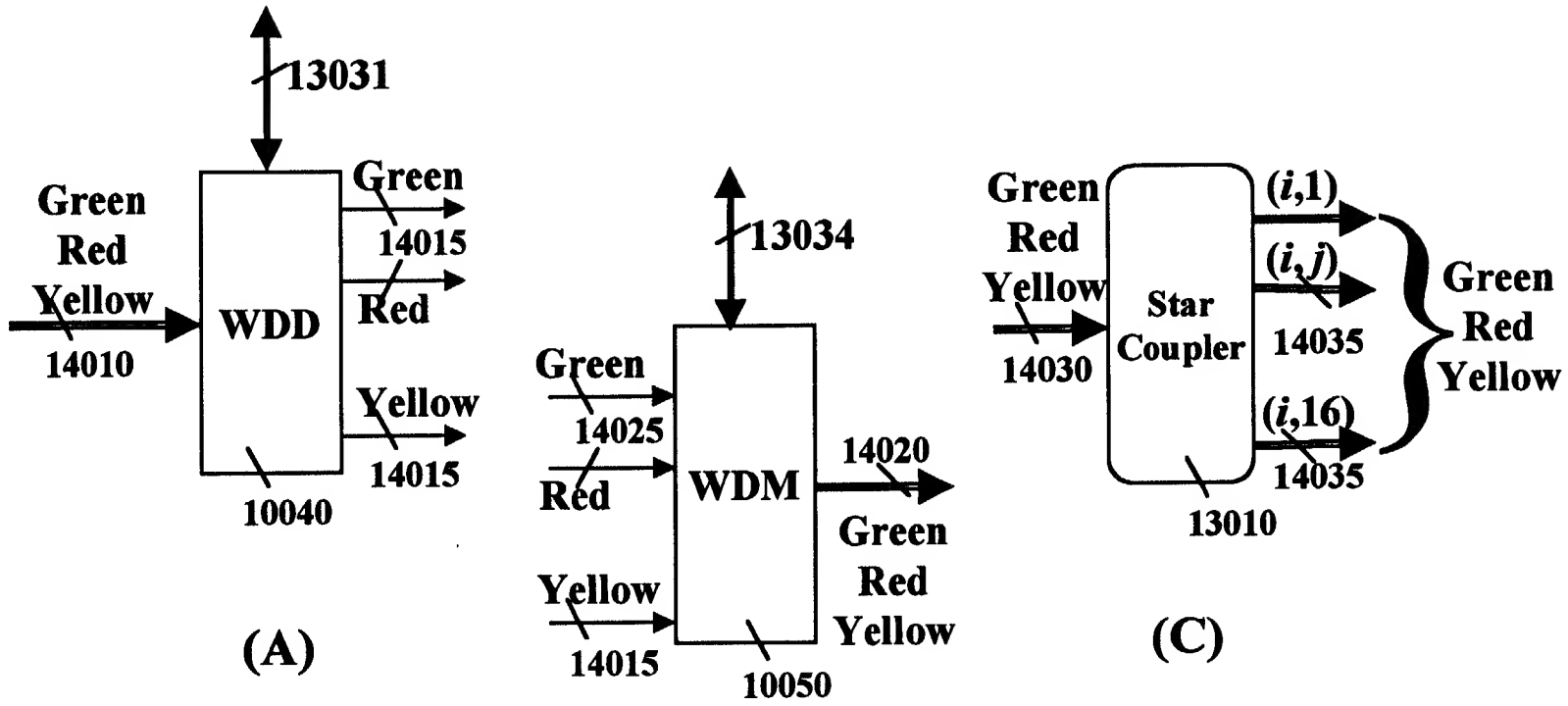
13031
Green
Red
Yellow
14010
WDD
Green
14015
Red
Yellow
14015
10040
(A)
13034
Green
14025
Red
Yellow
14015
WDM
14020
Green
Red
Yellow
10050
(B)
Green
Red
Yellow
14030
Star
Coupler
(i,1)
(i,j)
14035
(i,16)
14035
Green
Red
Yellow
13010
(C)

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FIG. 25

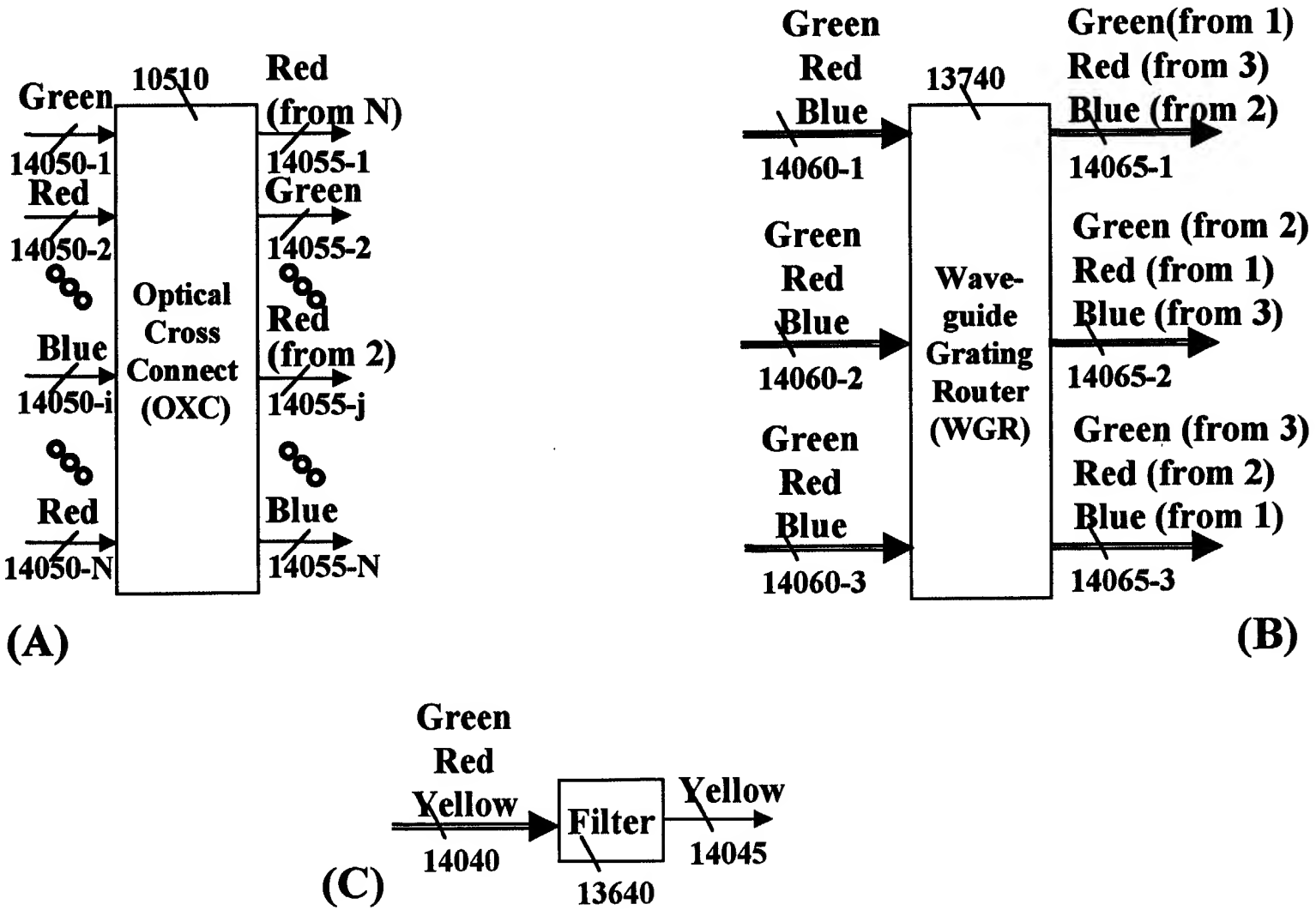

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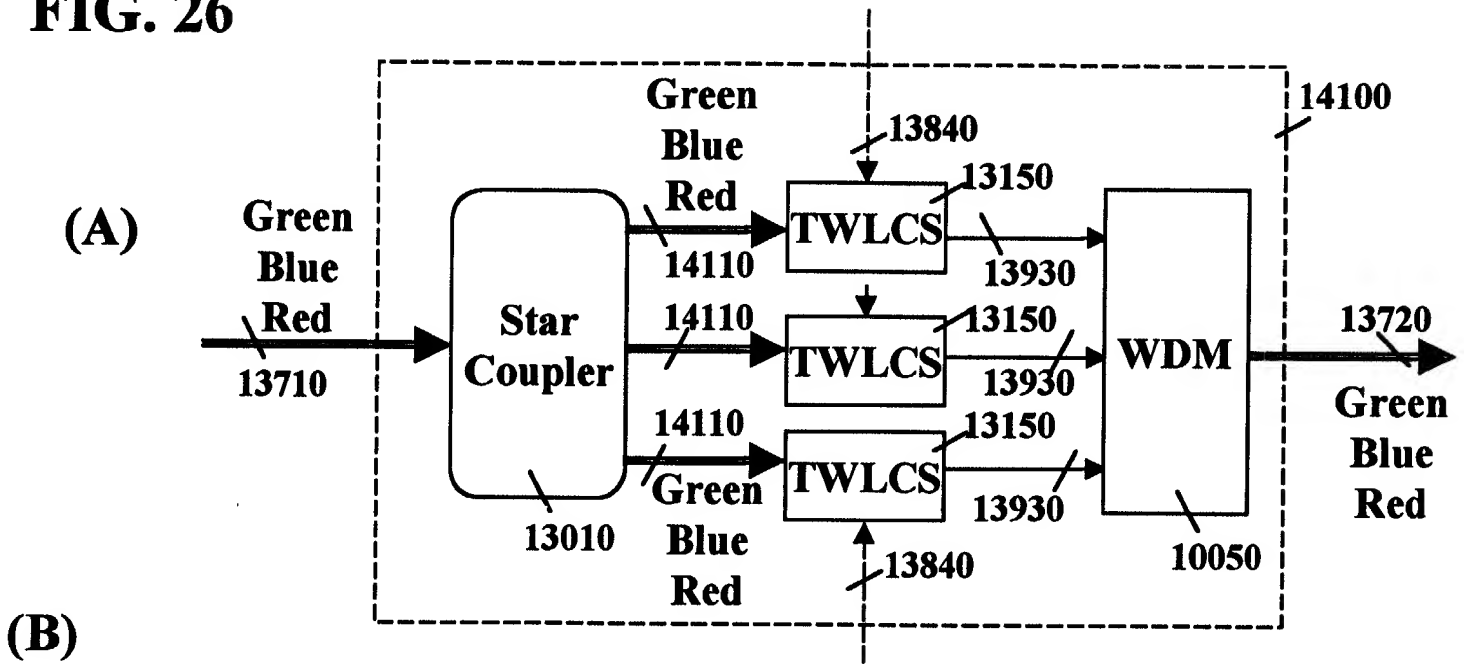
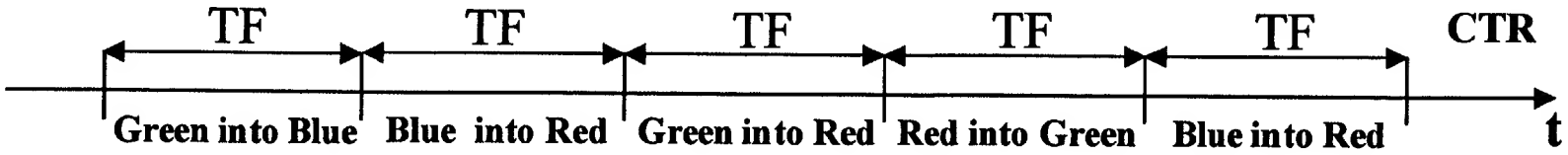
FIG. 26



(B)

Operation of a Tunable Wavelength Conversion Subsystem (TWLCS) 13150



Wavelengths received (on line 14110) and emitted (on line 13930) by a Tunable Wavelength Conversion Subsystem 13150

FIG. 27

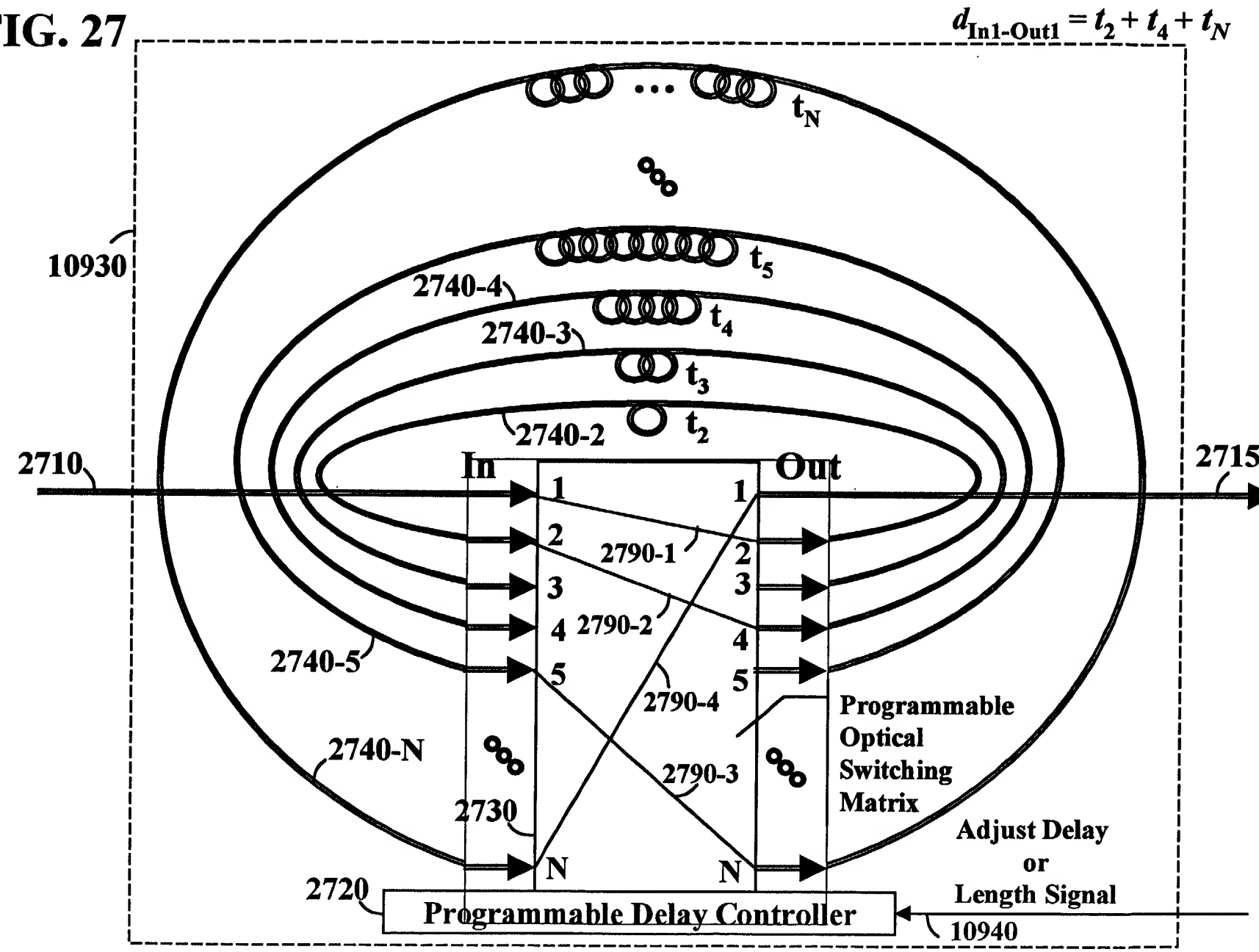

$d_{In1\text{-}Out1} = t_2 + t_4 + t_N$
10930
2740-4
2740-3
2740-2
2740-5
2740-N
t_N
t_5
t_4
t_3
t_2
2710
2715
In
Out
1
2
3
4
5
N
2790-1
2790-2
2790-3
2790-4
2730
Programmable Optical Switching Matrix
Adjust Delay or Length Signal
10940
2720
Programmable Delay Controller

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FIG. 28

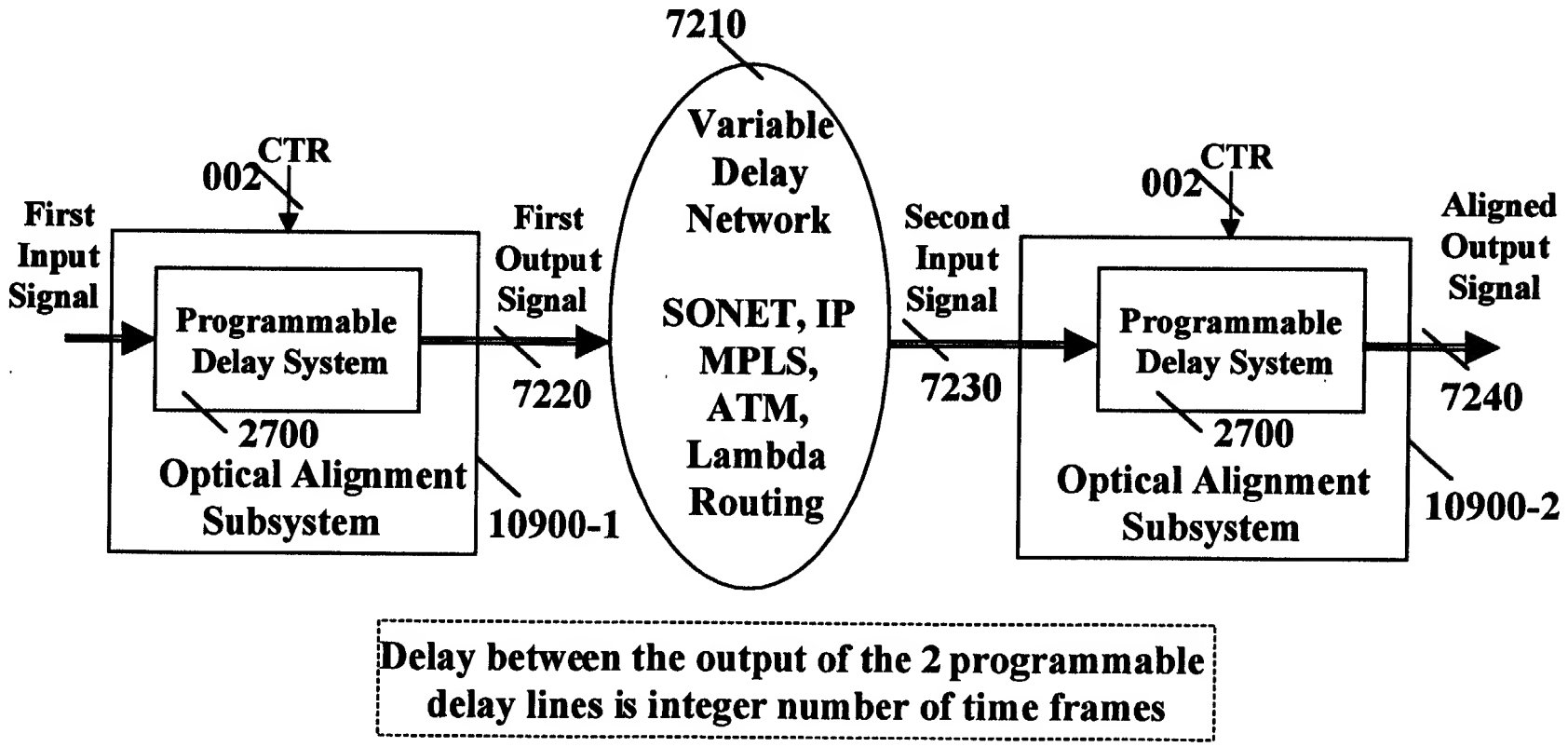


FIG. 29

***TF Alignment of* UTR(*i*) *to* UTC -** **with three input queues - principle of operation:**

The same queue is not used simultaneously for:

1. **Receiving data packets from the serial link, and**
2. **Forwarding data packets to the switch**

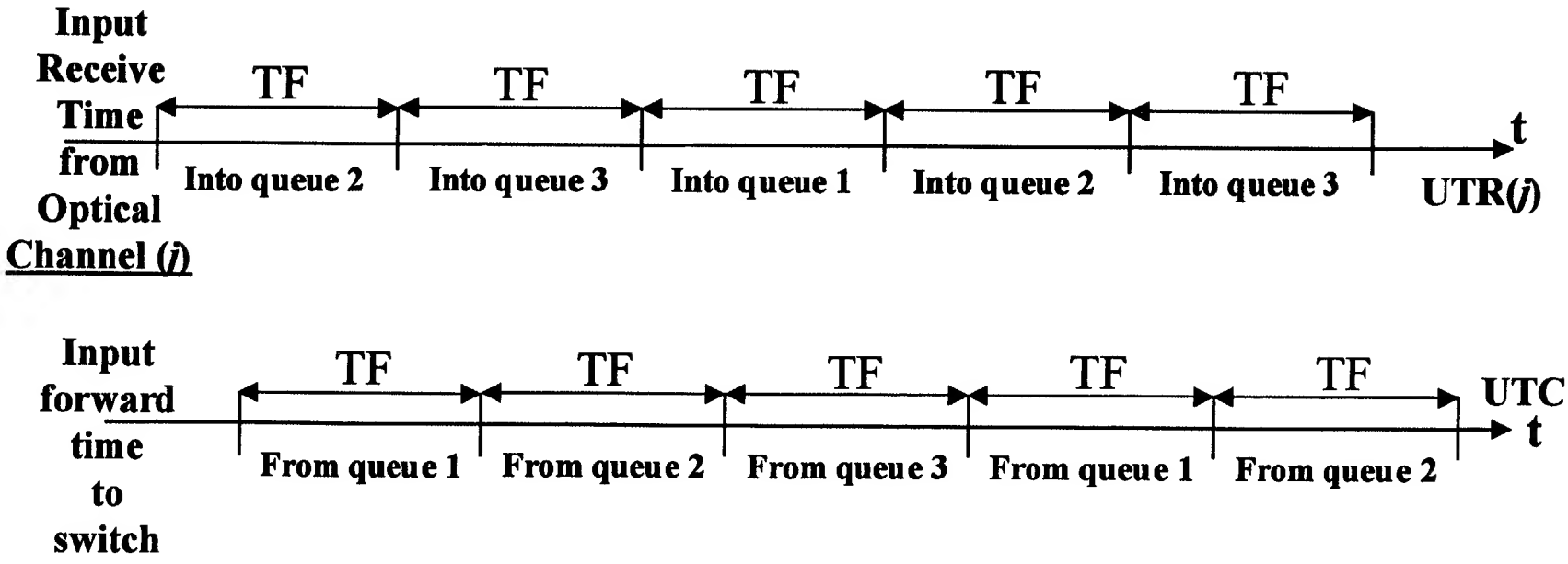
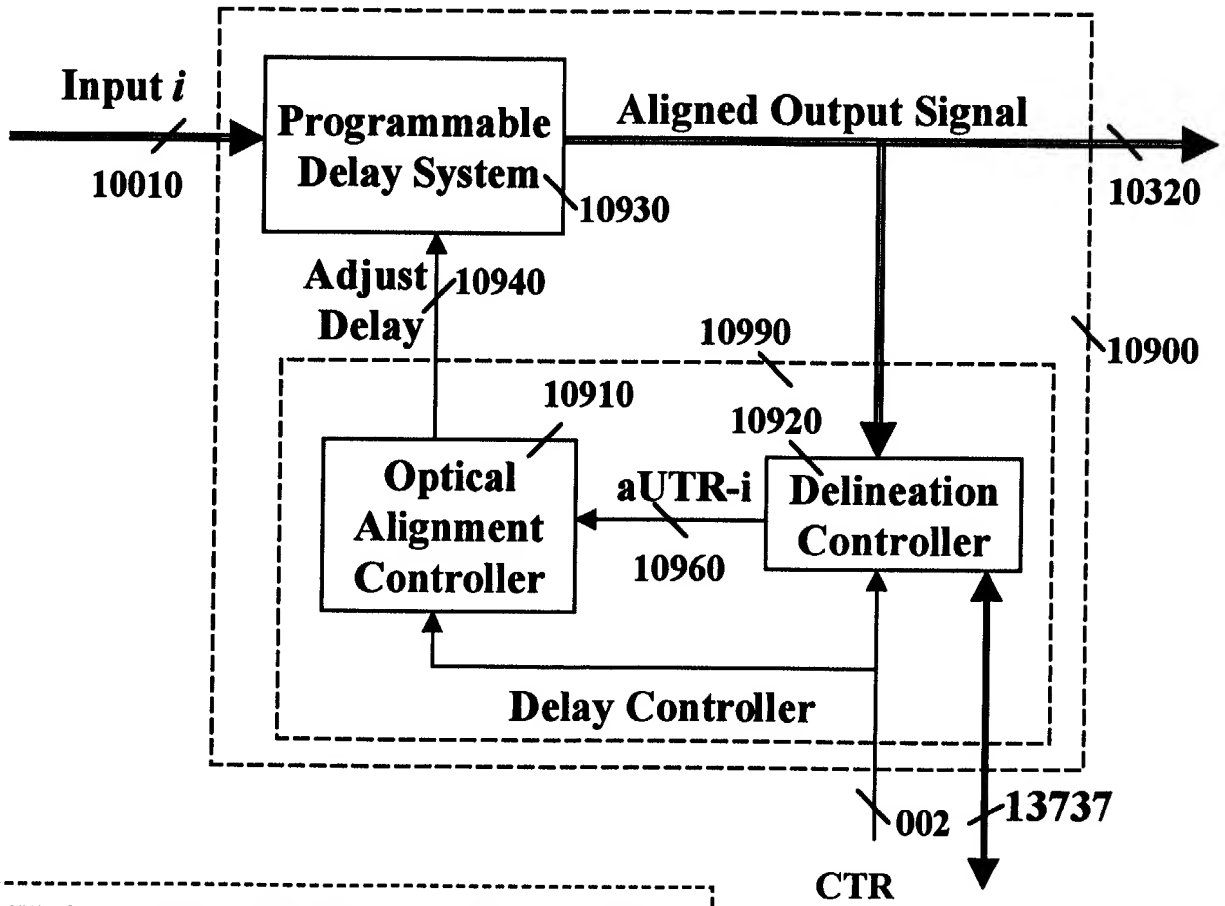


FIG. 30



UTR-i: Unique Time Reference of input link *i*
CTR: Common Time Reference

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FIG. 31

POSM: Programmable Optical Switching Matrix

$d_{In1\text{-}Out1} = t_1 + 2 \cdot t_2 + 3 \cdot t_N$

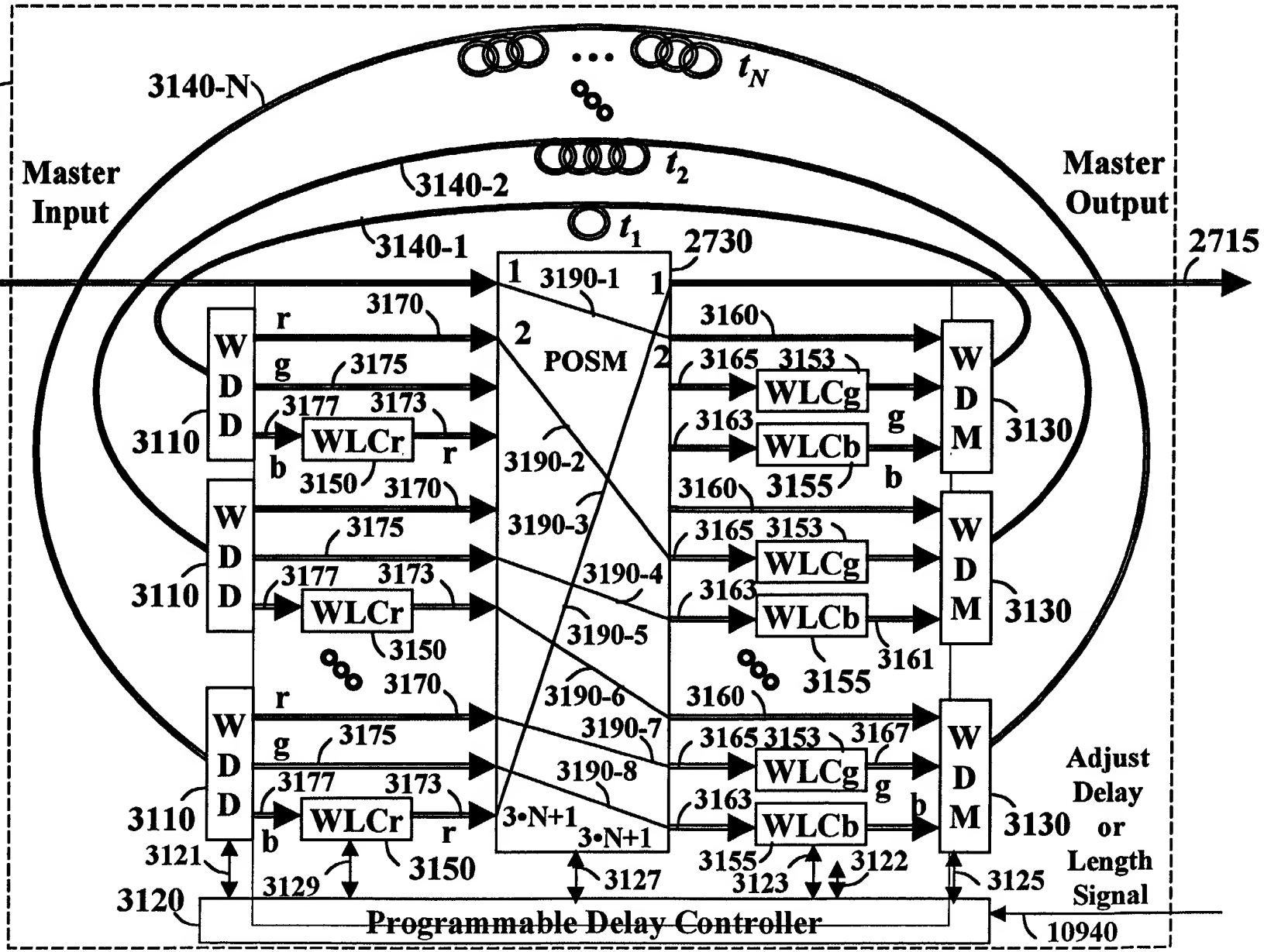

FIG. 32

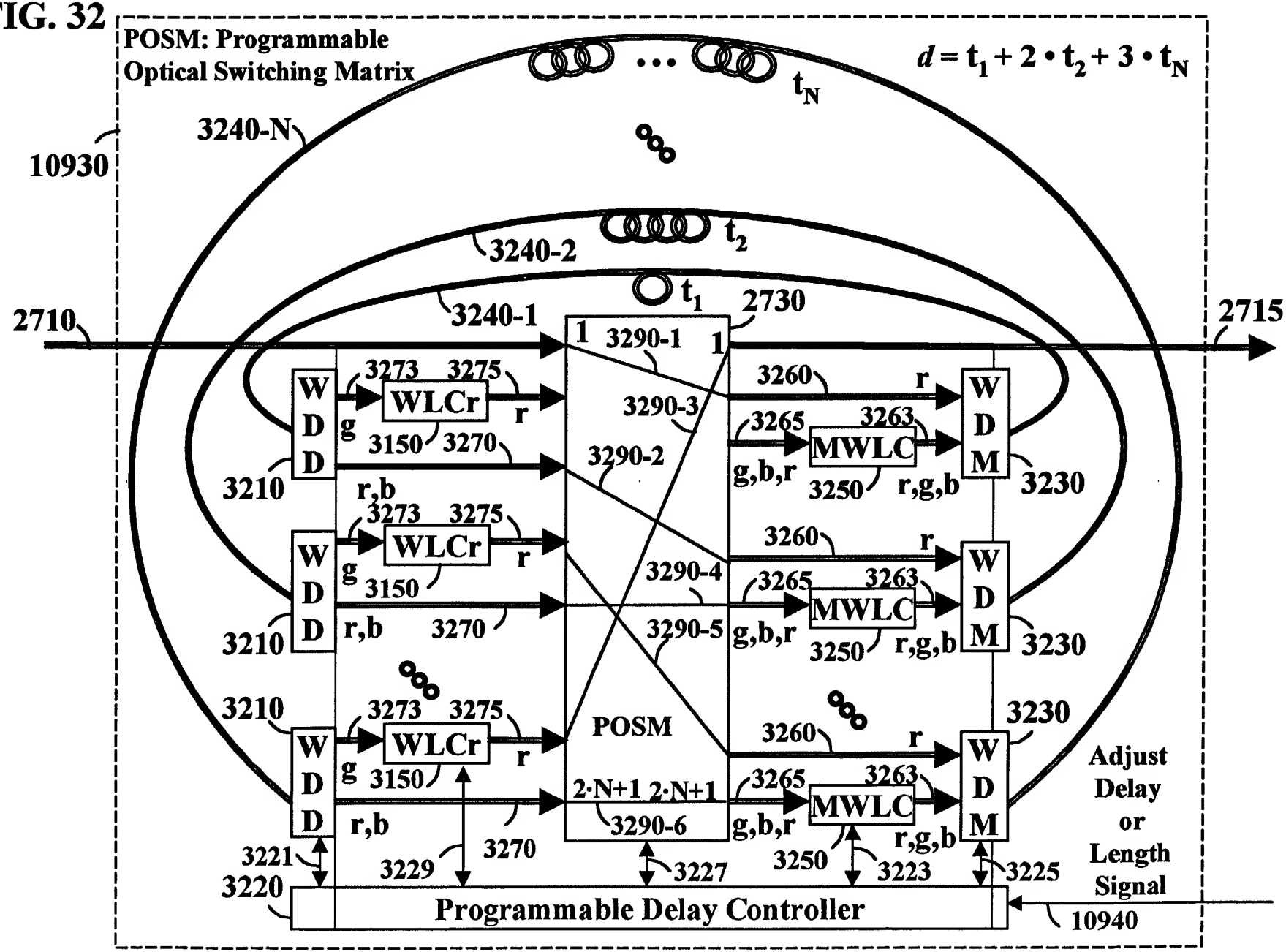
POSM: Programmable
Optical Switching Matrix
$d = t_1 + 2 \cdot t_2 + 3 \cdot t_N$
10930
3240-N
t_N
3240-2
t_2
3240-1
t_1
2710
2730
2715
1
3290-1
1
3290-3
3290-2
3290-4
3290-5
2·N+1 2·N+1
3290-6
POSM
WDD
WLCr
3273
3275
r
g
3150
3270
r,b
3210
MWLC
3260
3265
3263
g,b,r
r,g,b
3250
WDM
3230
3221
3220
3229
3227
3223
3225
Programmable Delay Controller
Adjust
Delay
or
Length
Signal
10940

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FIG. 33

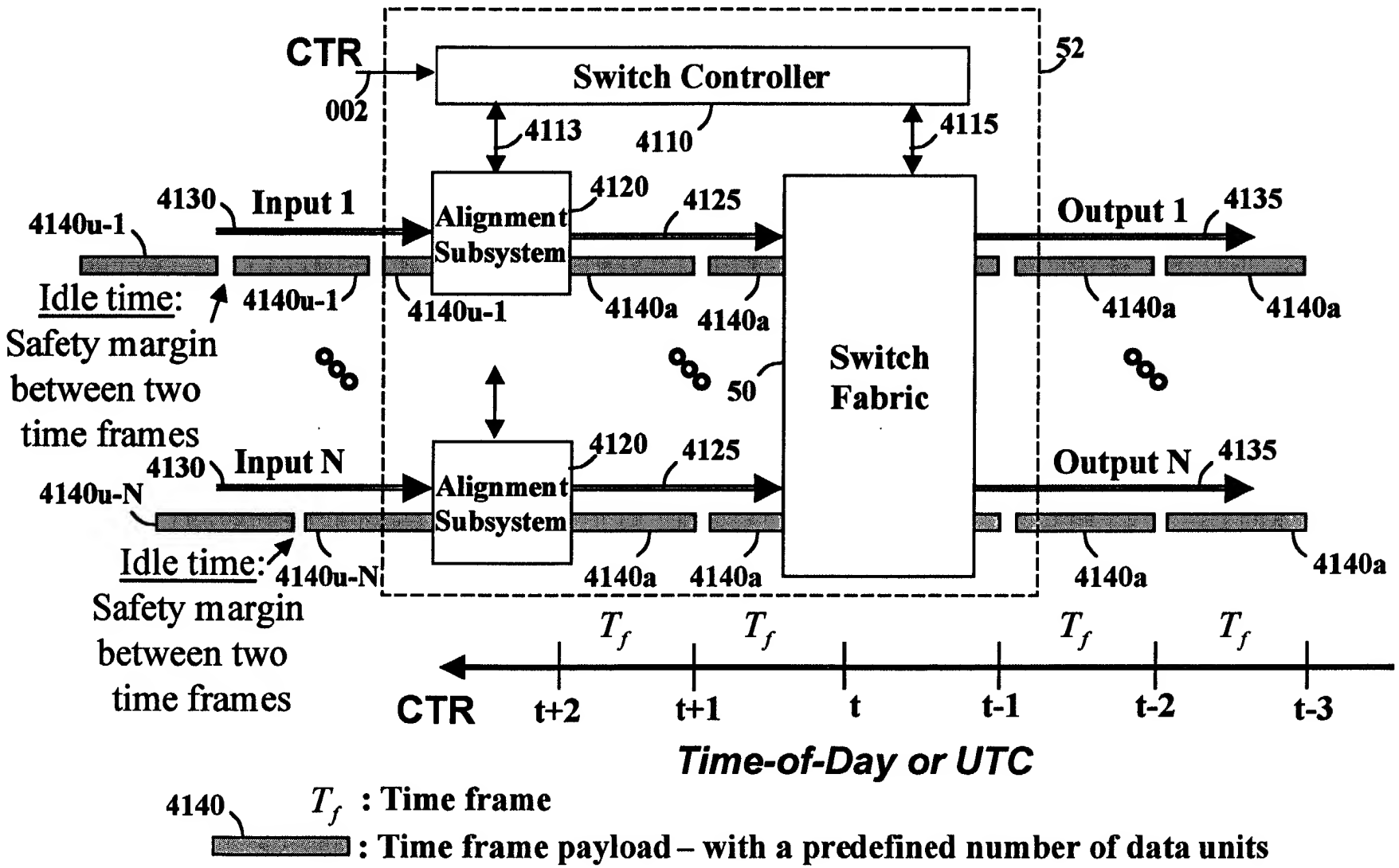


FIG. 34

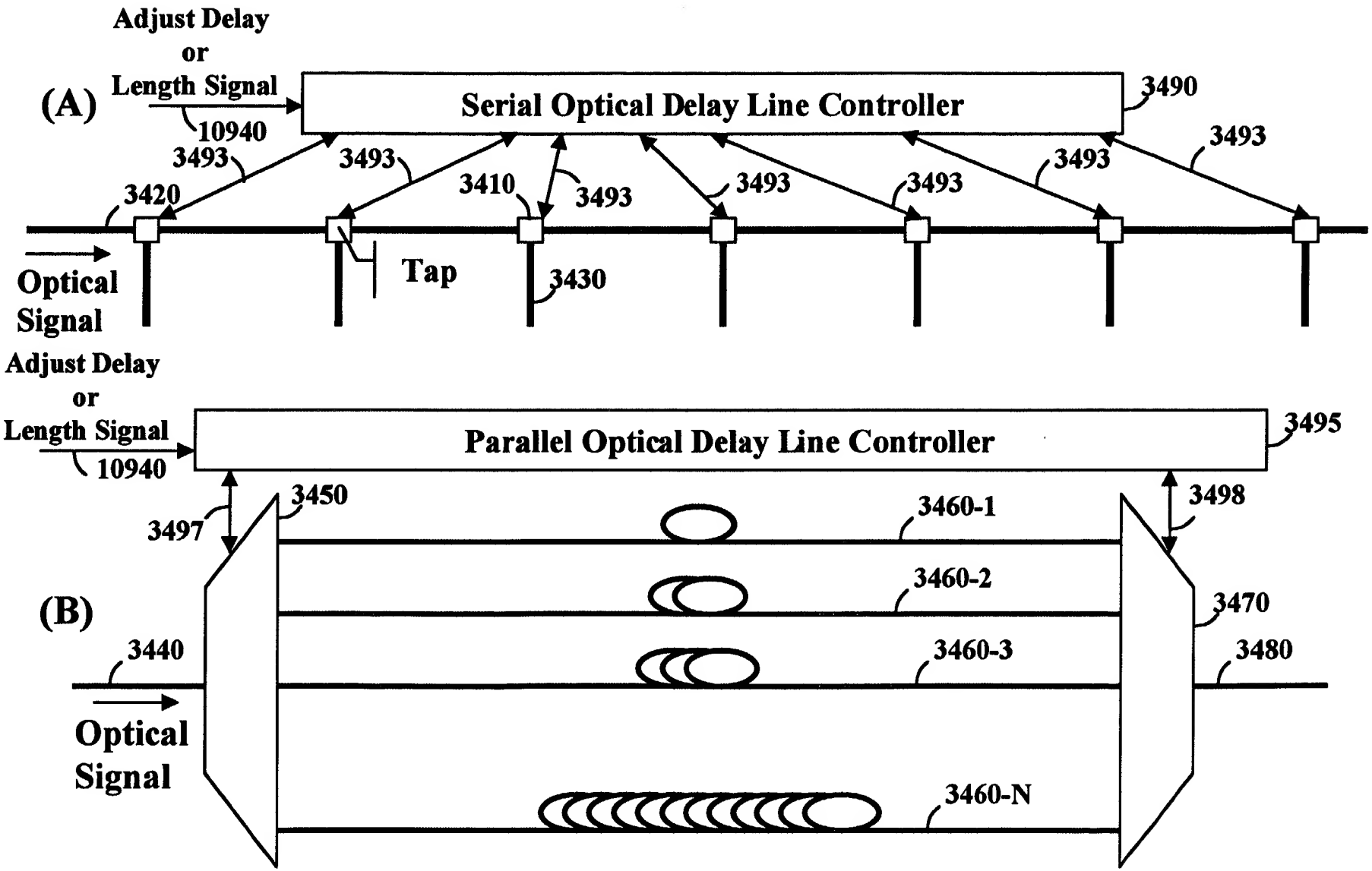
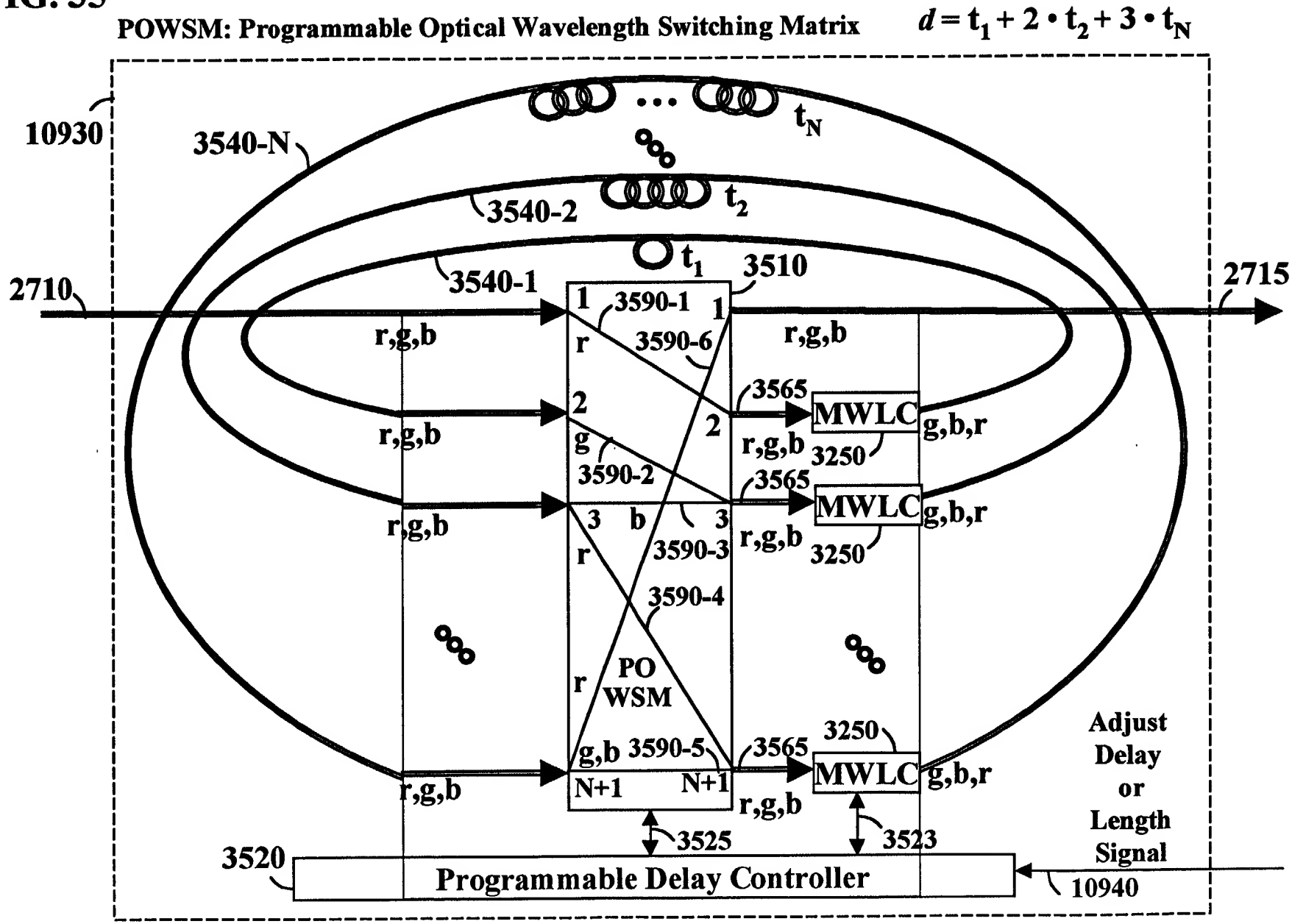

Adjust Delay
or
Length Signal
10940
(A)
Serial Optical Delay Line Controller
3490
3493
3420
3410
Tap
3430
Optical
Signal
Adjust Delay
or
Length Signal
10940
Parallel Optical Delay Line Controller
3495
3497
3450
3498
3460-1
3460-2
3460-3
3460-N
(B)
3440
3470
3480
Optical
Signal

FIG. 35


POWSM: Programmable Optical Wavelength Switching Matrix
$d = t_1 + 2 \cdot t_2 + 3 \cdot t_N$
10930
3540-N
3540-2
3540-1
t_N
t_2
t_1
2710
2715
3510
3590-1
3590-6
3590-2
3590-3
3590-4
3590-5
PO WSM
r,g,b
3565
MWLC
g,b,r
3250
3520
Programmable Delay Controller
3525
3523
Adjust Delay or Length Signal
10940